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REPORT

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FINAL REPORT ~~FOR~~

COMMAND AND COMMUNICATION SYSTEM TEST SET

GROUND SUPPORT EQUIPMENT

CONTRACT NO. NAS 8-20546

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SECTION I

1.0 INTRODUCTION AND SUMMARY

Motorola is submitting this final report to complete the final requirements of Contract NAS 8-20546. It covers the period from June 1, 1966 to September 1, 1966. In addition, it summarizes some of the significant events of the CCS Test Set program since the beginning. Included are technical achievements, schedules, additional test data, and recommendations.

SECTION II

2.0 REVIEW AND ACCOMPLISHMENTS

2.1 SUMMARY OF SCOPE AND CHANGES

The contract was signed on 3 December 1965. It provided for the delivery of five (5) Command & Communications System (CCS) Transponder Test Sets with suitable documentation, and limited personnel training at both Kennedy Space Center (KSC) and Marshall Space Flight Center (MSFC). Delivery of the first unit was initially scheduled to be 17 weeks after contract award. Subsequent units were scheduled to be delivered in 3-week intervals, except that the last 2 were to be delivered concurrently. The actual shipping dates agreed upon, test set configuration, and destination are summarized as follows:

Date	Serial No.	To	Type of Racks	Inter-rack Cabling
4 April	1	MSFC (for IBM)	Motorola	Top
25 April	2	KSC	GFE	Top
16 May	3	MSFC (for IBM)	Motorola	Top
6 June	4	KSC	GFE	Top
6 June	5	MSFC	Motorola	Lower-Rear

On 3 January 1966, Motorola was verbally redirected to provide an automatic precision ranging system in place of the one specified in the original work statement. Significant features of this system were agc of the clock, automatic code acquisition, and a 1 nanosecond resolution Range Delay Counter. It was agreed that Test Set S/N's 1, 2, and 3 would be delivered without any ranging system. Serial No.'s 4 and 5 would have the ranging capability included at delivery. Then S/N's 1, 2, and 3 would be retrofitted in the field at 3-week intervals following the delivery of the last test set.

During a subsequent meeting in January, other changes were discussed in addition to the ranging and were later incorporated into the system by a contract Modification Number 2. These items were:

1. The addition of an automatic sweep decay circuit for use in carrier acquisition tests.
2. The addition of a 600 kHz VCO in each of the 5 systems.
3. Addition of the capability to adjust the output of the TWT Power Amplifier continuously.
4. The addition of an audio monitor for the receiver and 2 head sets in each of the 5 systems.
5. Provisions for a 100K output impedance on the transponder telemetry functions. These were originally specified to be 10K.
6. Change the input to the PCM Telemetry 1.024 MHz Bi-Phase Modulator from single-ended to double-ended balanced to ground at the front panel of the modulation control.
7. Provide 5-20 MHz crystal filters with 2 kHz bandpass, for installation on the Hewlett-Packard RF Spectrum Analyzer.
8. Make provisions for monitoring the external telemetry function of the transponder when the Test Set is in the VAB or PAD modes.
9. Add a drawer (Antenna Status drawer) with lights, amplifiers, and power supply for the purpose of monitoring the condition of r-f switches external to the Test Set.

Due to above changes, a revised delivery schedule was agreed upon which is summarized as follows:

Test Sets	Shipping Date	Destination
S/N 1	4-13-66	MSFC
S/N 2	4-28-66	KSC
S/N 3	5-14-66	MSFC
S/N 4	6-23-66	MSFC
S/N 5	6-8-66	KSC

Ranging Retrofit to be included in S/N 4 and S/N 5.

Retrofit for	Shipping Date
S/N 1	6-23-66
S/N 2	6-8-66
S/N 3	6-23-66

During February and March, the program slipped behind schedule due to a variety of problems, such as parts shortages, the impact of the changes, and technical problems associated with the first unit. During April a meeting was held with key personnel from both MSFC and Motorola. Technical and schedule problems were discussed in detail. MSFC requested a firm schedule commitment from Motorola for all deliverable items. Motorola assured MSFC that major emphasis was being placed on the program. The revised schedule was presented to MSFC and is summarized.

DELIVERABLE ITEMS	DELIVERY SCHEDULE AT DESTINATION (Assuming Shipment in an Electronic Van)
Test Set	
S/N 1, less Ranging	5-14-66
S/N 2, less Ranging	6-20-66
S/N 3, less Ranging	7-10-66
S/N 5, complete	8-10-66
S/N 4, complete	8-28-66
Ranging Retrofit	
S/N 1 and S/N 3	8-28-66
S/N 2	8-10-66
Antenna Status Panel	
S/N 1	6-15-66
S/N 2	6-30-66
S/N 3, 4, 5	Concurrent with Test Set S/N 3, 4, 5

DELIVERABLE ITEMS	DELIVERY SCHEDULE AT DESTINATION (Assuming Shipment in an Electronic Van)
Documentation	
Preliminary Draft Documentation	Concurrent with Test Set S/N 1, 2, 3
Final Documentation with copies concurrent with -	
2 ea Test Set S/N 5	8-10-66
2 ea Test Set S/N 2, Retrofit	8-10-66
2 ea Test Set S/N 1, 3, Retrofit	8-28-66
2 ea Test Set S/N 4	8-28-66
Documentation Reproducibles, 2 ea	9-1-66
Final Report	9-8-66
Full Size Documentation Reproducibles	9-8-66

After the checkout and test of System No. 1, technical problems were uncovered which Motorola investigated on subsequent units. Numerous meetings were held to determine how important the problems were and the extent of the fixes. These problems were:

1. VCO phase jitter was within spec, but it was felt that it could be improved.
2. The r-f leakage was not completely covered by the specification and some deficiencies were found.
3. PCM driver did not meet all of the desired requirements, although it did meet the procurement specification.
4. The Hughes TWT Amplifier did not meet the RFI specification.
5. A transient was observed when switching between MGC and AGC which was out of spec.
6. Sporadic oscillation in the receiver AGC loop.

It was agreed that all but the MGC/AGC transient would be fixed either prior to delivery or in the field as a retrofit. A more detailed discussion of the problems and solutions follow.

The r-f leakage problem included: (1) The Test Transmitter leaking into the Transponder Receiver during the Self Test mode; (2) the Transponder Transmitter output leaking into the Test Receiver during the Self Test and VAB modes; and (3) the Test Transmitter output leaking into the Transponder Receiver, around the uplink attenuator, in VAB and PAD modes. The first two problems were resolved by relocating some of the coaxial relays and installing rigid coaxial cables in appropriate places. The third problem was corrected by relocation and shielding of a coaxial relay; shielding an isolator; and soldering rigid coaxial cable to connectors.

The VCO phase jitter problem was evaluated during checkout of S/N 1. A new ruggedized crystal mount was incorporated and a new circuit layout was implemented on later units. As a result of the design improvement, the performance of the later VCO's was found to be reliable and repeatable. The combined transmitter/receiver phase jitter over the total tuning range averaged between 4° to 4.5° rms in the 40 Hz loop. The specification required a maximum of 7°.

It was agreed that the PCM driver module would be redesigned. This was accomplished and the new module was found to meet all of the requirements necessary to interface with the transponder.

The first delivered Hughes TWT Amplifier failed to meet the radiated interference limits of MIL-I-6181 and was returned to the vendor for repair. It was repaired and retested at Motorola. The tests proved successful and the unit was shipped to KSC for installation in S/N 2 Test Set. The improvements made in the first TWT were incorporated in the second unit prior to shipment from Hughes.

The receiver AGC amplifier oscillation was evaluated and fixed with the addition of a capacitor.

The various problems and associated solutions were implemented prior to delivery or as part of a field retrofit program.

Table II-1 summarized the status of the Test Sets as they were delivered and the retrofits performed.

2.2 REVIEW OF SCHEDULED AND ACTUAL DELIVERY DATES

The following summary indicates schedule performance with respect to delivery of completed hardware.

	ITEM DESCRIPTION	ORIG SCHED DEL DATE	REVISED DEL DATE	ACTUAL SHIPPING DATE
1.	Test Set S/N 1 (less Ranging and Antenna Status Panel)	4-13-66	5-14-66	5-7-66
2.	Test Set S/N 2 (less Ranging and Antenna Status Panel)	4-28-66	6-20-66	6-6-66 Note 1.
3.	Test Set S/N 3 (less Ranging)	5-4-66	7-10-66	6-24-66 Note 2.
4.	Test Set S/N 4	6-23-66	9-1-66	8-1-66
5.	Test Set S/N 5	6-8-66	8-14-66	7-20-66
6.	Ranging Equipment (Retrofit for S/N 1)	6-23-66	9-1-66	7-29-66
7.	Antenna Status Panel & 600 kHz Osc. for S/N 2	Not Applicable	6-30-66	6-11-66
8.	Antenna Status Panel & 600 kHz Osc. for S/N 1	Not Applicable	6-15-66	6-30-66

Note 1. Test Set S/N 2 was originally scheduled to be delivered less Ranging Equipment; however, it was possible to incorporate the Ranging Equipment in this set and avoid the retrofit effort. This was done at some delay in shipment of the Test Set.

Note 2. Test Set S/N 3 was originally scheduled to be delivered without Ranging Equipment and retrofitted. This was not necessary as Ranging Equipment was available in time to be incorporated in S/N 3.

	VCO Ø Jitter	New PCM Driver	Install & Update Ranging	RF Leakage Change	TWT RFI	Antenna Status Drawer	AGC Ampl. Oscillation	600 kHz SCO
S/N 1	New VCO's installed in second retrofit	Installed in first retrofit*	Installed in first retrofit*	Incorporated as part of retrofit	Not included	Installed as part of first retrofit*	Installed as part of first retrofit	Installed as part of first retrofit
S/N 2	OK as delivered	Installed in first retrofit*	Modified in first retrofit	Incorporated as part of retrofit	Returned to vendor & fixed*	Shipped & installed at KSC	OK as delivered	Shipped & installed at KSC
S/N 3	OK as delivered	Shipped and installed at MSFC	Modified in first retrofit	Incorporated as part of retrofit	Not included	OK as delivered	OK as delivered	OK as delivered
S/N 5	OK as delivered	OK as delivered	Modified in first retrofit	Incorporated as part of retrofit**	OK as delivered	OK as delivered	OK as delivered	OK as delivered
S/N 4	OK as delivered	OK as delivered	OK as delivered	Incorporated as part of retrofit**	Not included	OK as delivered	OK as delivered	OK as delivered

*Shipped to MSFC or KSC, as required. Was installed in first retrofit program.

** VAB mode leakage only, all other leakage change incorporated prior to shipment.

Table II-1.
Test Set Status

2.3 SIGNIFICANT TECHNICAL ACHIEVEMENTS

A considerable amount of effort was expended in assuring that the Test Set would meet all of the technical objectives, namely: (1) Meet specifications as called out in the Work Statement, (2) Provide capability for completely evaluating the CCS Transponder, (3) Provide an accurate simulation of the MSFN Ground Station, and (4) Provide a flexible switching arrangement so that tests may be conducted accurately with a minimum of set up time. The following is a more detailed discussion of the significant technical achievements.

2.3.1 MSFN Simulation

Because the Test Set is designed to test a transponder that is to be compatible with NASA's Manned Space Flight Network, an early ground rule was established that this Test Set simulate the MSFN Ground Station equipment as much as possible. Motorola has built all of the types of equipment so represented in the MSFN. The Test Set, then, is essentially, identical to the MSFN equipment. Similarities/differences are as follows:

a. Transmitter: The same electrical characteristics as represented in the MSFN Receiver-Exciter-Ranging Subsystem that Motorola has built for NASA.

b. Test Receiver: The same electrical characteristics (in many cases, the exact same modules) that Motorola has made for NASA. The only exceptions were that the crystal filter in the IF Amplifier was changed to reduce the "pushing effect" (false lock), and a low noise parametric amplifier was not included.

c. The 70 kHz Subcarrier Oscillator and the 1.024 MHz PCM Demodulator has the same electrical characteristics as the MSFN.

d. The 70 kHz Demodulator and 1.024 MHz Modulator, which are used to check the Test Set 70 kHz Subcarrier Oscillator and the 1.024 MHz PCM Demodulator, have characteristics similar to those in the CCS Transponder.

e. The Ranging Codes are the same as that used by the MSFN. The Ranging Subsystem itself, however, is different from that used in the MSFN System because the MSFN Ranging Subsystem was not designed to check transponders. (See para. 2.3.3)

2.3.2 RF Leakage, Isolation, and RF Path Accuracy

It was a requirement of the Test Set that the r-f path be accurate to within ±2 db as a requirement, and to within ±1 db as a design goal, over the full range of 170 db, smoothly continuous. The steps that had to be taken to meet these requirements were as follows:

1. Extremely accurate, continuously variable r-f attenuators were necessary, with some sort of redundancy, to give the user a confidence in the attenuator accuracy.
2. Switchable attenuators could not be used to increase the range from 120 db to 170 db, so a continuously variable attenuator, calibrated in 10 db steps, was necessary.
3. To meet the additional requirement of high power out of the Transmitter drawer for certain modes, it was necessary to use a variable attenuator with low insertion loss.
4. To allow the Test Receiver to operate as a threshold receiver without switching the variable attenuator out of the circuit, an attenuator with low insertion loss was required.
5. In order to meet the r-f path accuracy, and minimize interference from one mode to another, it was necessary to keep the r-f leakage to an extremely low value.

To meet the requirements of the above, the following designs were incorporated:

1. Two Narda Type 784 variable attenuators were used, one in the Test Receiver and one in the Test Transmitter. They were calibrated by Narda, traceable to the National Bureau of Standards, at the

appropriate frequencies of 2101 or 2282 MHz. They were also spot-checked by Motorola's Test Equipment Lab and were in full agreement. In the SELF TEST mode, one attenuator could be "played" against the other attenuator, to give the operator a measure of comparative accuracies of the two attenuators.

2. The "step" attenuator in the Test Transmitter consisted of a PRD 198 variable attenuator, calibrated in 10 db steps. This attenuator is used in the SELF TEST and BENCH modes. Calibration of this attenuator is performed by comparing its attenuation to that of the Narda 784 in the Transmitter.

3. & 4. The Narda attenuator described above has an insertion loss of less than 1 db. Thus, the power out of the Test Transmitter drawer was typically +12 dbm maximum, while requiring only +17 dbm out of the X24 Multiplier. For the Test Receiver, the noise figure at the input to the Test Receiver drawer (Part I) was degraded by only 1.7 db typically over that measured at the preselector input, typically 8.5 db.

5. RF leakage and interference presented possibly the most challenging problems of the CCS Test Set. Some of the techniques that were used to solve these problems were as follows:

   a. S-band r-f components were placed within a homogeneous aluminum box, made so by dip brazing the entire box.

   b. The top and bottom covers of the r-f boxes were gasketed with a double-layer of r-f gasketing; many screws were used to keep even pressure on the gasketing.

   c. Everything (except S-band) entering or leaving the r-f boxes was filtered with suitable r-f filters, in the case of signals, or controlled by non-conducting rods through tubes that represent a waveguide beyond cutoff. These tubes were welded to the appropriate wall.

d. Separate compartments were used when a large amount of isolation was required for a particular item. The Narda attenuators, for instance, were placed in their own compartment, with one connector of the attenuator protruding through the wall, and r-f gasketed so leakage would not occur around the attenuator.

e. Solid shielded coax cable was used where it was necessary to reduce the S-band leakage through the wall of the coax, such as to another coax or a "hot" item.

f. To achieve high isolation between different modes, coax relays with 70 db isolation (at S-band) were used. However, the relays used had poor isolation from coax to out of the relay (50 db or more), so in some cases, it was necessary to relocate some of these relays.

2.3.3 Ranging Subsystem (Delay Measurement)

The sophisticated ranging subsystem represents a significant technical achievement because of its accuracy, range of operation, and ease of operation. This subsystem is essentially a second generation of the ranging subsystem that Motorola developed for the Apollo Block II Special Test Equipment. Some of the salient aspects of this ranging subsystem are as follows:

1. It develops the same ranging codes that the MSFN ground station will use for actual flight.
2. The accuracy of measuring the transponder delay is exceptionally high for all modes and types of operation. To achieve this accuracy, it was necessary to eliminate all VCO's in the Ranging Receiver, which give an inherent change in delay for a loop stress.

3. Ease of operation of the ranging subsystem, to the point of being fool-proof, was a prime requirement of the ranging subsystem. This is particularly true in the automatic modes. Flexibility was required also, so the ranging subsystem may be operated in any one or all of the manual modes. These automatic/manual modes are:

   a. Gain control to compensate for different modulation combinations and signal levels into the Transponder Receiver.

   b. Acquisition of the PN codes.

   c. Ranging delay measurements.

2.3.4 Ease of Operation

Of paramount importance in the design of the CCS Test Set was ease of operation. All functions that are necessary to monitor are immediately available at one or more monitor points merely by pushing a pushbutton, which gives the name of the function to be monitored (these functions are shown on the Test Set Block Diagram). No patching of cables is necessary. Yet, flexibility is maintained by providing pushbuttons, complete with relays, for additional functions that may be added later. Additional flexibility is accomplished by allowing additional equipment to monitor these selected functions merely by placing the additional test equipment across the input to one of the built in test equipment. Thus, all normal functions are displayed on oscilloscopes, a spectrum analyzer, and/or a wave analyzer for maximum visual display of electrical functions. In most instances, there is redundant measurement techniques allowed; such as, frequency using a counter or a scope, voltage using a scope, RMS VTVM, wave analyzer, etc. Other techniques, such as momentary pushbuttons and colored indicator lights for specific reasons, show that the Test Set was "human engineered" for minimum operator problems.

2.3.5 Long Term Stability

Prime on MSFC's list of requirements was good, long term stability. This Test Set was designed to be stable by the use of inherently stable circuits, oven-controlled components and even subassemblies, and high negative feedbacks, where necessary. In addition, critical subassemblies were checked for drift and proper operation over the temperature range from $0^{o}C$ to $+55^{o}C$. The acceptance tests included a long term stability test (10 hours) on 9 separate parameters to prove the stability of each Test Set.

2.3.6 Radio Frequency Interference

Since the CCS Test Set was to be used at Kennedy Space Center, it was necessary that the Test Set not emanate interferring signals. Therefore, the Test Set was designed to suppress or contain interferring signals. The entire Test Set was tested to the radiated and conducted interference limits of MIL-I-6181D, with only two failures on the initial tests. Both of these failures were fixed. One failure was due to a piece of purchased equipment that did not meet Motorola's RFI requirements, and was subsequently fixed by the vendor. The other failure was a minor failure that was brought within specification limits by proper termination.

SECTION III

3.0 SYSTEM DESCRIPTION

3.1 GENERAL

The Command and Communications Test Set consists of four standard racks of drawers, designed and built by Motorola, Inc., off-the-shelf (commercial) test equipment, and power supplies. Circuit breakers are provided in each rack.

3.2 PURPOSE

The purpose of this Test Set is to check out the Command and Communications Transponder in four different situations. These four situations or modes of operation for the Test Set are BENCH XPNDR, BENCH PA, VAB, and PAD modes. A SELF TEST mode for the Test Set is also provided.

In BENCH XPNDR and BENCH PA modes, the transponder and PA are mounted in the drawer provided in the Test Set. In the VAB, the Test Set is connected to the transponder by long cables and in the PAD mode the Test Set TWT Amplifier is put in operation and an air-link is used to the transponder. (Antennas are not provided.)

3.3 FUNCTIONS

Functionally, the Test Set transmits a precisely controlled S-band r-f signal, with various subcarriers and modulation, to the transponder under test, receives the S-band r-f signal reply from the transponder and demodulates the various subcarriers and modulation. In the process, it evaluates a number of transponder parameters. The Test Set provides the following functions:

a. Four modes of operation, BENCH XPNDR, BENCH PA, VAB or PAD, and SELF TEST.

b. Transponder and PA Mount drawer for the units under test and power for them.

c. A stable S-band PM Test Transmitter.

d. A phase-coherent S-Band Receiver Subsystem.

e. A phase-coherent Ranging Subsystem.

f. A Demodulator for recovering subcarriers and the information from the Test Receiver.

g. A means of measuring power output and modulation characteristics of the Transponder Transmitter.

h. A Transponder and Power Amplifier Control Panel for monitoring and controlling the power to and telemetry from the transponder.

i. A TWT Power Amplifier to obtain an additional 10 watts through an external antenna to form an air-link between the Test Set and the transponder in the PAD mode.

3.4 TRANSPONDER TEST SET CAPABILITIES

In the BENCH XPNDR and BENCH PA modes, the tests in the following list may be performed on the transponder.

a. Receiver center frequency

b. Receiver tracking range

c. Receiver tracking rate capability and acquisition capability

d. Threshold sensitivity

e. Receiver tracking loop bandwidth

f. Receiver AGC voltage versus input signal level

g. Receiver SPE voltage versus input frequency

h. Receiver 70 kHz subcarrier demodulation

1. Sensitivity
2. Signal-to-noise ratio at output
3. Frequency response
4. Phase response (delay change versus modulating frequency)

The following transponder (downlink) transmitter parameters can be tested with or without the power amplifier, and in either the voltage controlled oscillator (VCO) or the auxiliary oscillator (aux. osc.) mode.

a. Transmitter frequency

b. Transmitter power output

c. Transmitter spurious outputs

d. Transmitter phase noise

e. 1.024 MHz subcarrier oscillator and bi-phase modulator performance:

   1. Subcarrier frequency (and frequency stability)

   2. Subcarrier modulation index

   3. Bi-phase modulator input sensitivity

   4. Subcarrier spectrum and carrier suppression

   5. Predetection signal-to-noise ratio

   6. Post-detection signal-to-noise ratio

In the VAB mode, transponder tests which can be performed are:

a. Acquisition

b. Tracking capability

c. Threshold sensitivity

d. Transmitter frequency (aux. osc.)

e. Range delay

f. 70 kHz subcarrier performance

g. 1.024 MHz subcarrier frequency, frequency stability, and predetection signal-to-noise ratio

In the PAD mode, the same tests can be performed as in the VAB mode by use of the Test Set TWT Power Amplifier and appropriate antenna considerations (not supplied).

3.5 TEST SET FUNCTIONAL BLOCKS

The Test Set consists of a number of separate subsystems as follows:

3.5.1 Test Transmitter

The Test Transmitter function is entirely contained in one r-f tight drawer. It generates a phase-stable S-band carrier capable of being phase modulated.

3.5.2 Modulation Control

The Modulation Control is packaged in one drawer and provides (1) the 70 kHz and 1.024 MHz subcarriers, (2) a square wave for modulating the 1.024 MHz subcarrier, and (3) modulation interfaces between external input, PN code input, etc. and the phase modulator located in the Test Transmitter. The sweep and decay circuitry and transmitter VCO control are also located in this drawer.

3.5.3 Test Receiver

The Test Receiver Subsystem consists of three drawers: A Receiver Control drawer, an r-f tight receiver front end drawer, and a drawer containing the remaining receiver modules. This receiver has essentially the same characteristics as the MSFN receiver that is expected to receive S-band signals from the CCS Transponder in flight.

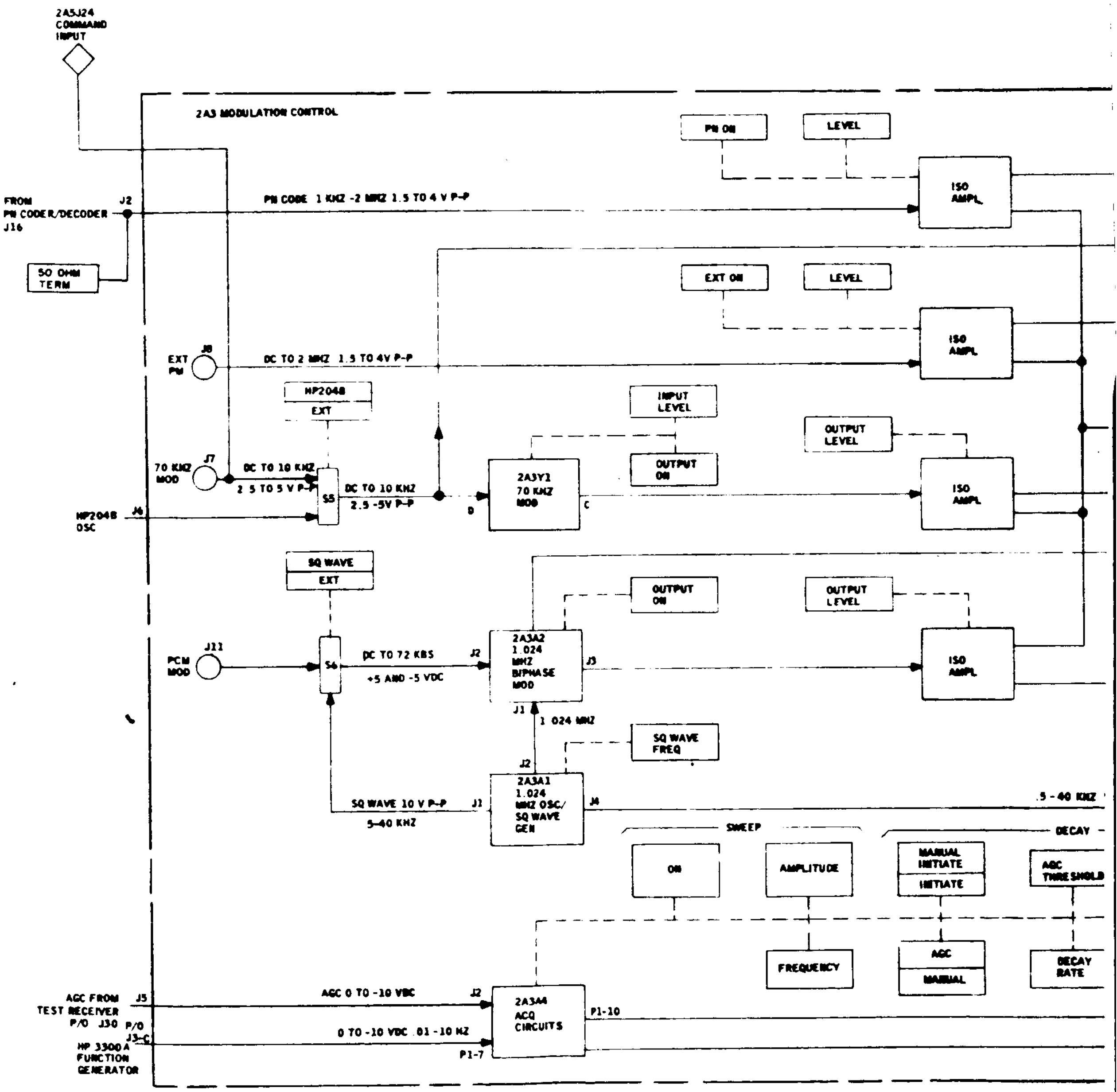
3.5.4 Demodulator

This subsystem is contained in one drawer and provides the capability of demodulating the subcarriers from the transponder signal and also demodulating the information off of the subcarriers.

The 1.024 MHz PCM Demodulator and the wideband FM Demodulator operate in a manner similar to the MSFN System. The 70 kHz Demodulator has characteristics similar to the 70 kHz Demodulator in the CCS Transponder.

3.5.5 Ranging Subsystem

The Ranging Subsystem is made up of three drawers. The Ranging Receiver and time interval counter were designed to allow an operator to accurately test a CCS



2A5J24
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J2
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PN ON
LEVEL
ISO
AMPL
EXT ON
LEVEL
EXT
PM
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DC TO 2 MHZ 1.5 TO 4V P-P
HP2048
EXT
INPUT
LEVEL
OUTPUT
ON
OUTPUT
LEVEL
70 KHZ
MOD
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2.5 TO 5 V P-P
S5
DC TO 10 KHZ
2.5 -5V P-P
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70 KHZ
MOD
HP2048
OSC
J6
SQ WAVE
EXT
OUTPUT
ON
OUTPUT
LEVEL
PCM
MOD
J11
S4
DC TO 72 KBS
+5 AND -5 VDC
2A3A2
1.024
MHZ
BIPHASE
MOD
J3
J1
1.024 MHZ
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FREQ
J2
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MHZ OSC/
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ON
AMPLITUDE
MANUAL
INITIATE
INITIATE
AGC
THRESHOLD
FREQUENCY
AGC
MANUAL
DECAY
RATE
AGC FROM
TEST RECEIVER
P/O J30
J5
AGC 0 TO -10 VDC
2A3A4
ACQ
CIRCUITS
P1-10
P/O
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GENERATOR
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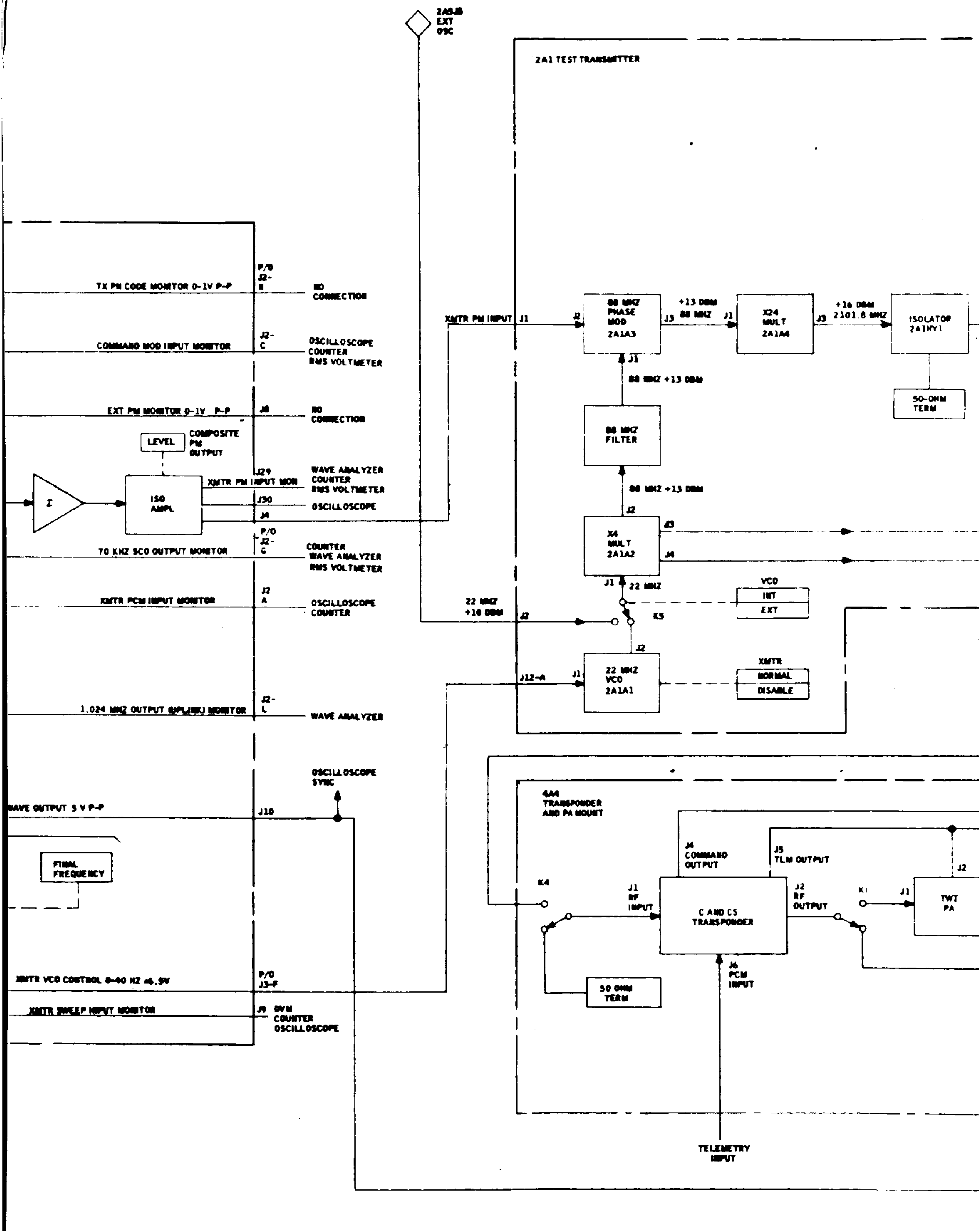
P1-7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J2-
C
OSCILLOSCOPE
COUNTER
RMS VOLTMETER
EXT PM MONITOR 0-1V P-P
J8
NO
CONNECTION
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PM
OUTPUT
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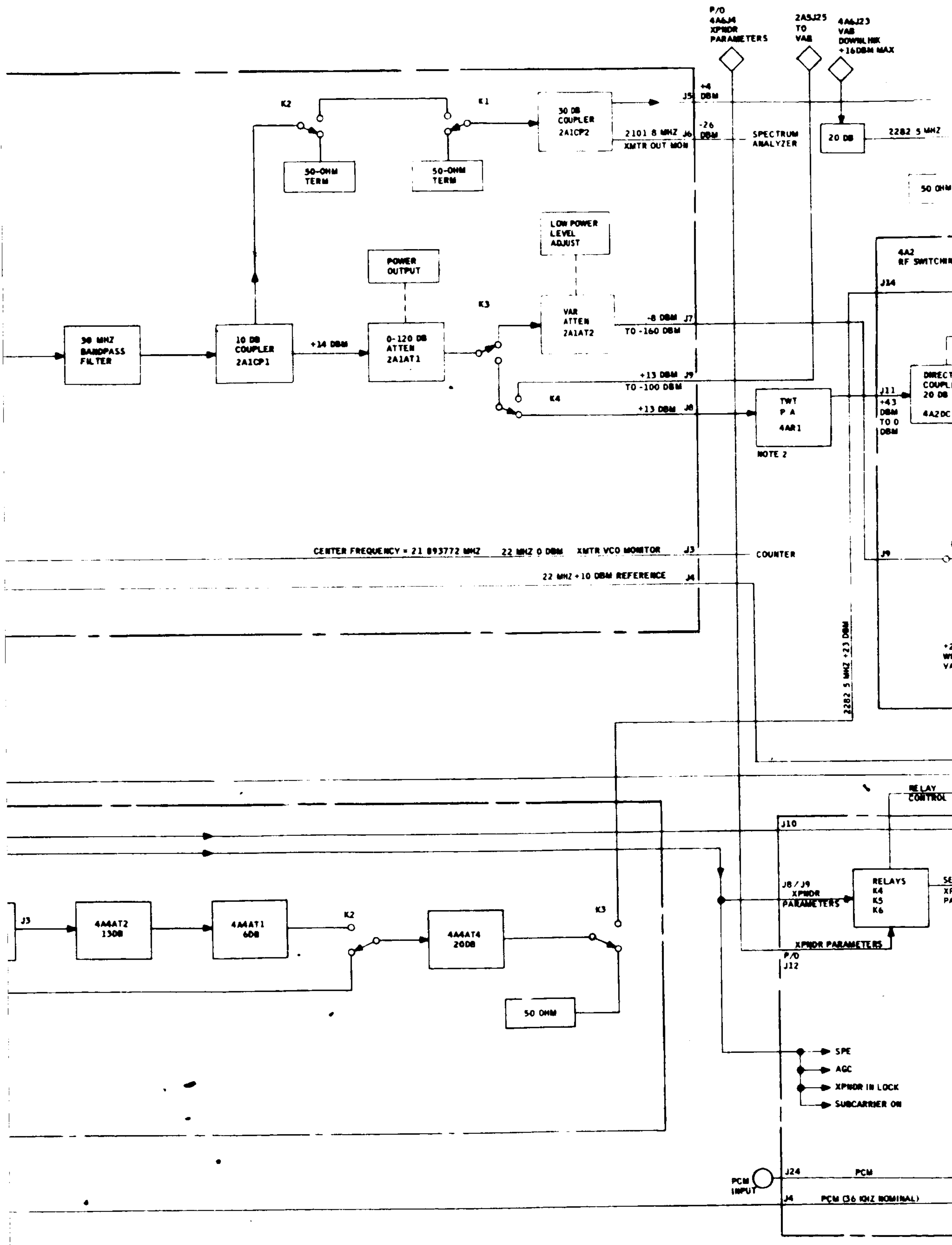
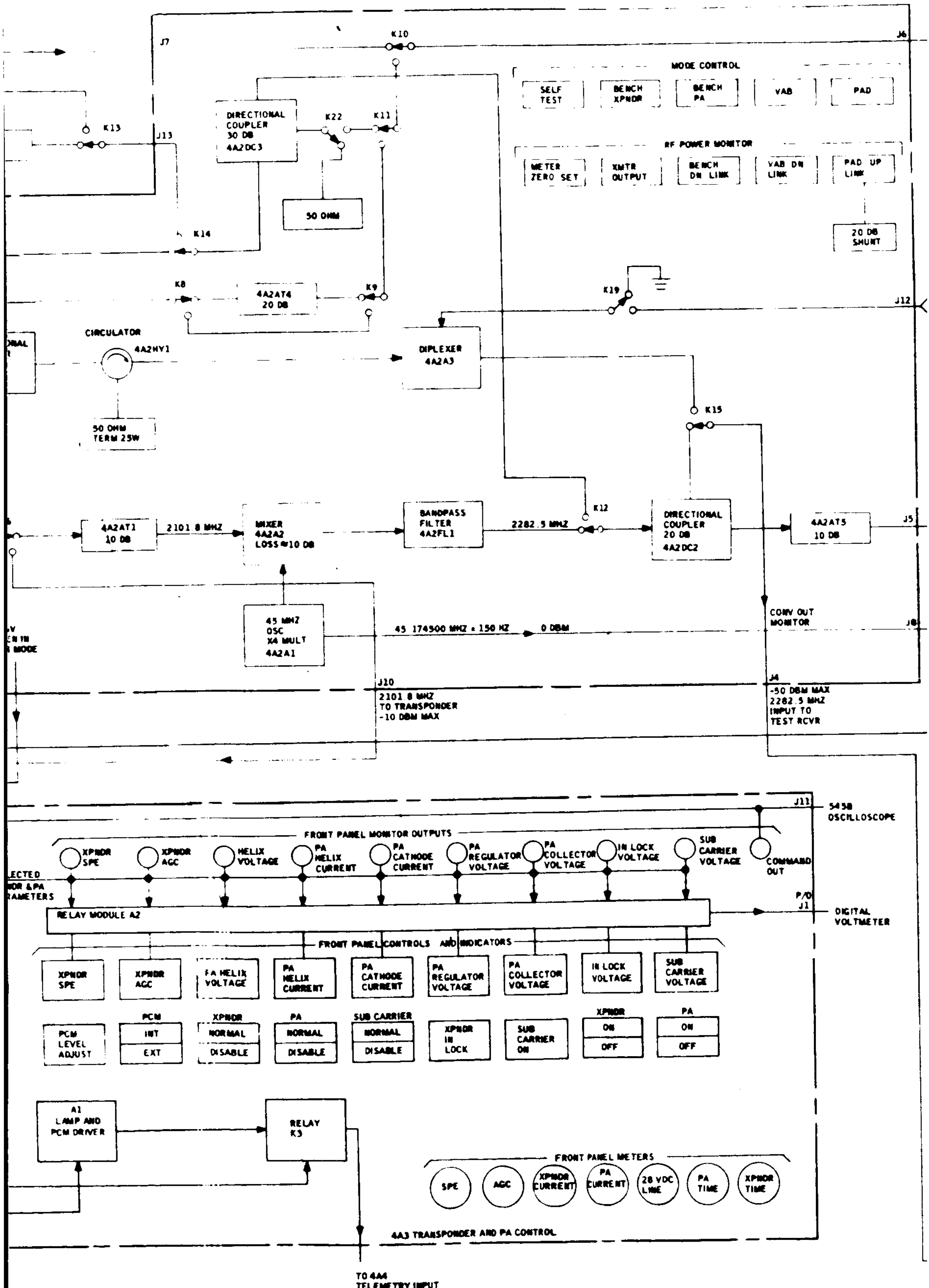
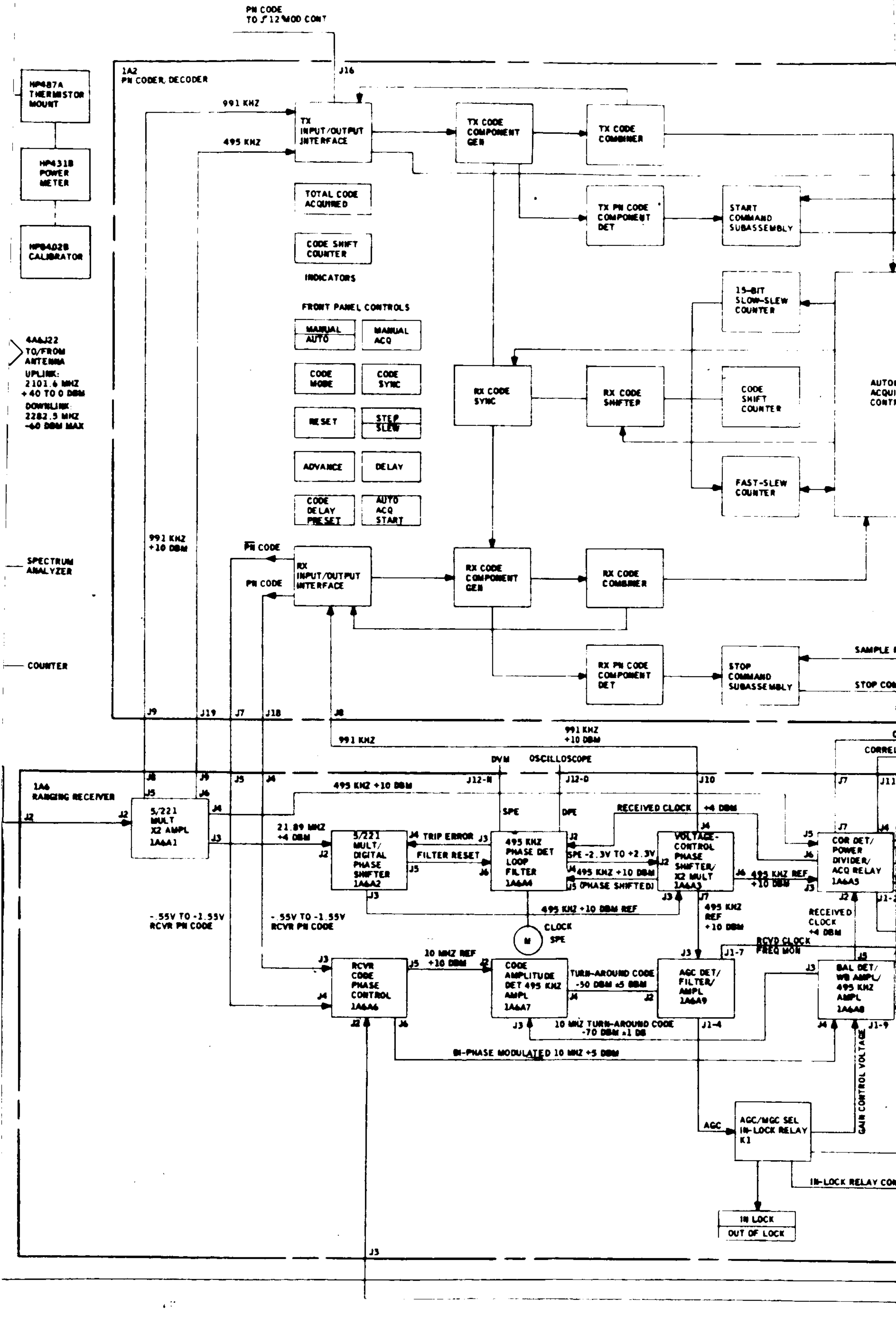
COUNTER
WAVE ANALYZER
RMS VOLTMETER
XMTR PCM INPUT MONITOR
J2
A
OSCILLOSCOPE
COUNTER
1.024 MHZ OUTPUT (UPLINK) MONITOR
J2-
L
WAVE ANALYZER
OSCILLOSCOPE
SYNC
WAVE OUTPUT 5 V P-P
J10
FINAL
FREQUENCY
XMTR VCO CONTROL 0-40 HZ ±6.5V
P/O
J3-F
XMTR SWEEP INPUT MONITOR
J9
DVM
COUNTER
OSCILLOSCOPE
XMTR PM INPUT
J1
J2
88 MHZ
PHASE
MOD
2A1A3
J3
+13 DBM
88 MHZ
J1
X24
MULT
2A1A4
J3
+16 DBM
2101.8 MHZ
ISOLATOR
2A1HY1
50-OHM
TERM
J1
88 MHZ +13 DBM
88 MHZ
FILTER
88 MHZ +13 DBM
J2
X4
MULT
2A1A2
J3
J4
J1
22 MHZ
VCO
INT
EXT
22 MHZ
+10 DBM
J2
K5
J2
XMTR
NORMAL
DISABLE
J12-A
J1
22 MHZ
VCO
2A1A1
4A4
TRANSPONDER
AND PA MOUNT
J4
COMMAND
OUTPUT
J5
TLM OUTPUT
J2
K4
J1
RF
INPUT
C AND CS
TRANSPONDER
J2
RF
OUTPUT
K1
J1
TWT
PA
50 OHM
TERM
J6
PCM
INPUT
TELEMETRY
INPUT



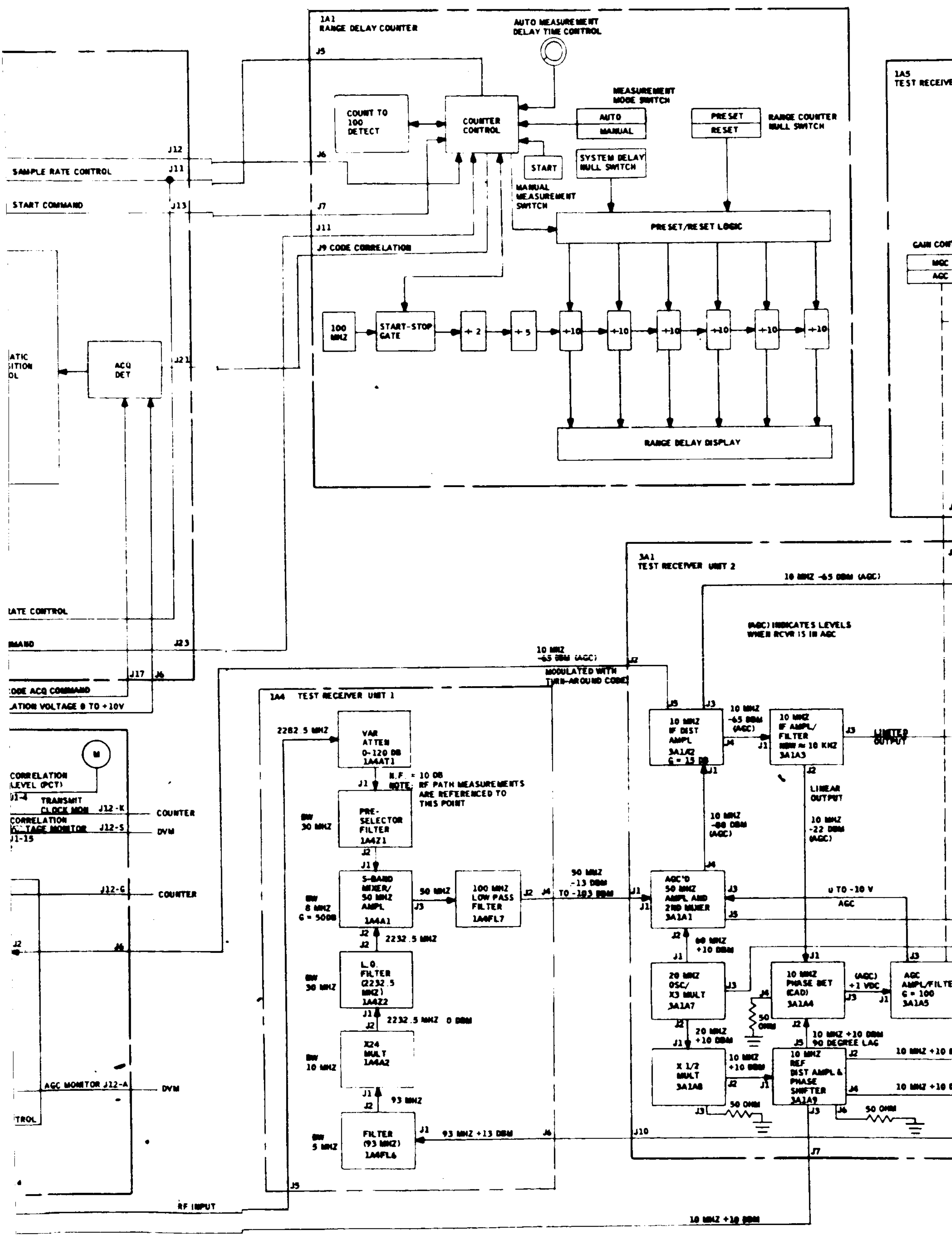
P/O 4A6J4 XPNDR PARAMETERS
2A5J25 TO VAB
4A6J23 VAB DOWNLINK +16DBM MAX
K2
K1
30 DB COUPLER 2A1CP2
+4 DBM
-26 DBM
2101 8 MHZ
XMTR OUT MON
SPECTRUM ANALYZER
20 DB
2282 5 MHZ
50-OHM TERM
50-OHM TERM
50 OHM
LOW POWER LEVEL ADJUST
POWER OUTPUT
4A2 RF SWITCHING
J14
K3
VAR ATTEN 2A1AT2
-8 DBM
TO -160 DBM
30 MHZ BANDPASS FILTER
10 DB COUPLER 2A1CP1
+14 DBM
0-120 DB ATTEN 2A1AT1
+13 DBM
TO -100 DBM
K4
+13 DBM
TWT P A 4AR1
NOTE 2
J11
+43 DBM TO 0 DBM
DIRECT COUPL 20 DB 4A2DC
CENTER FREQUENCY = 21 893772 MHZ
22 MHZ 0 DBM
XMTR VCO MONITOR
COUNTER
22 MHZ +10 DBM REFERENCE
2282 5 MHZ +23 DBM
RELAY CONTROL
J10
J8 / J9 XPNDR PARAMETERS
RELAYS K4 K5 K6
XPNDR PARAMETERS
P/O J12
4A4AT2 13DB
4A4AT1 6DB
4A4AT4 20DB
50 OHM
SPE
AGC
XPNDR IN LOCK
SUBCARRIER ON
PCM INPUT
J24
PCM
PCM (36 KHZ NOMINAL)



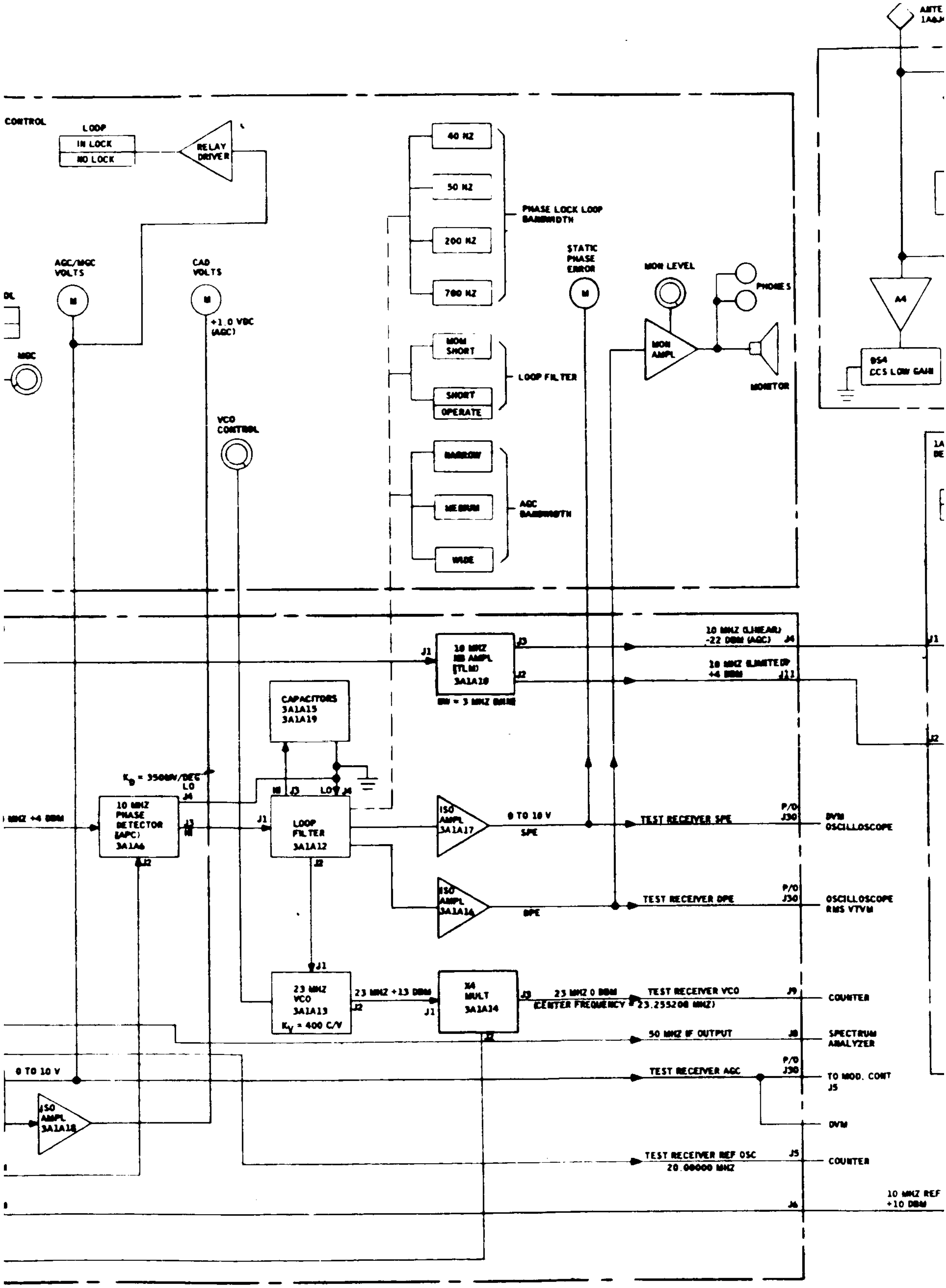
J7
K10
J6
MODE CONTROL
SELF TEST
BENCH XPNDR
BENCH PA
VAB
PAD
K13
J13
DIRECTIONAL COUPLER 30 DB 4A2DC3
K22
K11
RF POWER MONITOR
METER ZERO SET
XMTR OUTPUT
BENCH DN LINK
VAB DN LINK
PAD UP LINK
50 OHM
20 DB SHUNT
K14
K8
4A2AT4 20 DB
K9
K19
J12
CIRCULATOR
4A2HY1
DIPLEXER 4A2A3
50 OHM TERM 25W
K15
K12
4A2AT1 10 DB
2101.8 MHZ
MIXER 4A2A2 LOSS ≈10 DB
BANDPASS FILTER 4A2FL1
2282.5 MHZ
DIRECTIONAL COUPLER 20 DB 4A2DC2
4A2AT5 10 DB
J5
45 MHZ OSC X4 MULT 4A2A1
45.174500 MHZ ± 150 HZ
0 DBM
CONV OUT MONITOR
J8
J10
2101.8 MHZ TO TRANSPONDER -10 DBM MAX
J4
-50 DBM MAX 2282.5 MHZ INPUT TO TEST RCVR
J11
545B OSCILLOSCOPE
FRONT PANEL MONITOR OUTPUTS
XPNDR SPE
XPNDR AGC
HELIX VOLTAGE
PA HELIX CURRENT
PA CATHODE CURRENT
PA REGULATOR VOLTAGE
PA COLLECTOR VOLTAGE
IN LOCK VOLTAGE
SUB CARRIER VOLTAGE
COMMAND OUT
RELAY MODULE A2
P/O J1
DIGITAL VOLTMETER
FRONT PANEL CONTROLS AND INDICATORS
XPNDR SPE
XPNDR AGC
PA HELIX VOLTAGE
PA HELIX CURRENT
PA CATHODE CURRENT
PA REGULATOR VOLTAGE
PA COLLECTOR VOLTAGE
IN LOCK VOLTAGE
SUB CARRIER VOLTAGE
PCM LEVEL ADJUST
PCM INT EXT
XPNDR NORMAL DISABLE
PA NORMAL DISABLE
SUB CARRIER NORMAL DISABLE
XPNDR IN LOCK
SUB CARRIER ON
XPNDR ON OFF
PA ON OFF
A1 LAMP AND PCM DRIVER
RELAY K3
FRONT PANEL METERS
SPE
AGC
XPNDR CURRENT
PA CURRENT
28 VDC LINE
PA TIME
XPNDR TIME
4A3 TRANSPONDER AND PA CONTROL
TO 4A4 TELEMETRY INPUT



PN CODE
TO J12 MOD CONT
1A2
PN CODER, DECODER
J16
HP487A THERMISTOR MOUNT
HP431B POWER METER
HP8402B CALIBRATOR
4A6J22 TO/FROM ANTENNA
UPLINK: 2101.6 MHZ +40 TO 0 DBM
DOWNLINK: 2282.5 MHZ -60 DBM MAX
SPECTRUM ANALYZER
COUNTER
991 KHZ
495 KHZ
TX INPUT/OUTPUT INTERFACE
TX CODE COMPONENT GEN
TX CODE COMBINER
TOTAL CODE ACQUIRED
CODE SHIFT COUNTER
INDICATORS
TX PN CODE COMPONENT DET
START COMMAND SUBASSEMBLY
FRONT PANEL CONTROLS
MANUAL AUTO
MANUAL ACQ
CODE MODE
CODE SYNC
RESET
STEP SLEW
ADVANCE
DELAY
CODE DELAY PRESET
AUTO ACQ START
15-BIT SLOW-SLEW COUNTER
RX CODE SYNC
RX CODE SHIFTER
CODE SHIFT COUNTER
FAST-SLEW COUNTER
991 KHZ +10 DBM
PN CODE
PN CODE
RX INPUT/OUTPUT INTERFACE
RX CODE COMPONENT GEN
RX CODE COMBINER
RX PN CODE COMPONENT DET
STOP COMMAND SUBASSEMBLY
SAMPLE
STOP CO
J9 J19 J7 J18 J8
991 KHZ
991 KHZ +10 DBM
DVM
OSCILLOSCOPE
J12-N
J12-D
J10
CORREL
J8 J9 J5 J4
1A6 RANGING RECEIVER
J2
495 KHZ +10 DBM
5/221 MULT X2 AMPL 1A6A1
21.89 MHZ +4 DBM
5/221 MULT/ DIGITAL PHASE SHIFTER 1A6A2
TRIP ERROR
FILTER RESET
SPE
DPE
495 KHZ PHASE DET LOOP FILTER 1A6A4
RECEIVED CLOCK
+4 DBM
SPE -2.3V TO +2.3V
495 KHZ +10 DBM
(PHASE SHIFTED)
VOLTAGE-CONTROL PHASE SHIFTER/ X2 MULT 1A6A3
495 KHZ REF +10 DBM
COR DET/ POWER DIVIDER/ ACQ RELAY 1A6A5
495 KHZ +10 DBM REF
495 KHZ REF +10 DBM
RECEIVED CLOCK +4 DBM
-.55V TO -1.55V RCVR PN CODE
-.55V TO -1.55V RCVR PN CODE
CLOCK SPE
M
RCVD CLOCK FREQ MON
10 MHZ REF +10 DBM
RCVR CODE PHASE CONTROL 1A6A6
CODE AMPLITUDE DET 495 KHZ AMPL 1A6A7
TURN-AROUND CODE -50 DBM ±5 DBM
AGC DET/ FILTER/ AMPL 1A6A9
BAL DET/ WB AMPL/ 495 KHZ AMPL 1A6A8
10 MHZ TURN-AROUND CODE -70 DBM ±1 DB
IN-PHASE MODULATED 10 MHZ +5 DBM
GAIN CONTROL VOLTAGE
AGC
AGC/MGC SEL IN-LOCK RELAY K1
IN-LOCK RELAY CO
IN LOCK
OUT OF LOCK
J3



1A1
RANGE DELAY COUNTER
AUTO MEASUREMENT DELAY TIME CONTROL
MEASUREMENT MODE SWITCH
AUTO
MANUAL
PRESET
RESET
RANGE COUNTER NULL SWITCH
COUNT TO 100 DETECT
COUNTER CONTROL
START
SYSTEM DELAY NULL SWITCH
MANUAL MEASUREMENT SWITCH
PRESET/RESET LOGIC
J9 CODE CORRELATION
100 MHZ
START-STOP GATE
÷2
÷5
÷10
RANGE DELAY DISPLAY
SAMPLE RATE CONTROL
START COMMAND
ACQ DET
1A5
TEST RECEIVER
GAIN CONTROL
MGC
AGC
3A1
TEST RECEIVER UNIT 2
10 MHZ -65 DBM (AGC)
(AGC) INDICATES LEVELS WHEN RCVR IS IN AGC
10 MHZ -65 DBM (AGC)
MODULATED WITH TURN-AROUND CODE
1A4 TEST RECEIVER UNIT 1
2282.5 MHZ
VAR ATTEN 0-120 DB 1A4AT1
N.F. = 10 DB
NOTE: RF PATH MEASUREMENTS ARE REFERENCED TO THIS POINT
BW 30 MHZ
PRE-SELECTOR FILTER 1A4Z1
BW 8 MHZ G = 50DB
S-BAND MIXER/ 50 MHZ AMPL 1A4A1
50 MHZ
100 MHZ LOW PASS FILTER 1A4FL7
50 MHZ -13 DBM TO -103 DBM
2232.5 MHZ
BW 30 MHZ
L.O. FILTER (2232.5 MHZ) 1A4Z2
2232.5 MHZ 0 DBM
BW 10 MHZ
X24 MULT 1A4A2
93 MHZ
BW 5 MHZ
FILTER (93 MHZ) 1A4FL6
93 MHZ +13 DBM
10 MHZ IF DIST AMPL 3A1A2 G = 15 DB
10 MHZ -65 DBM (AGC)
10 MHZ IF AMPL/ FILTER NBW ≈ 10 KHZ 3A1A3
LIMITED OUTPUT
LINEAR OUTPUT
10 MHZ -22 DBM (AGC)
10 MHZ -80 DBM (AGC)
AGC'D 50 MHZ AMPL AND 2ND MIXER 3A1A1
0 TO -10 V
AGC
60 MHZ +10 DBM
20 MHZ OSC/ X3 MULT 3A1A7
10 MHZ PHASE DET (CAD) 3A1A4
(AGC) +1 VDC
AGC AMPL/FILTER G = 100 3A1A5
50 OHM
20 MHZ +10 DBM
10 MHZ +10 DBM 90 DEGREE LAG
X 1/2 MULT 3A1A8
10 MHZ +10 DBM
10 MHZ REF DIST AMPL & PHASE SHIFTER 3A1A9
10 MHZ +10 DBM
10 MHZ +10 DBM
50 OHM
50 OHM
CORRELATION LEVEL (PCT)
TRANSMIT CLOCK MON J12-K
COUNTER
CORRELATION VOLTAGE MONITOR J12-S
DVM
J12-G
COUNTER
AGC MONITOR J12-A
DVM
RATE CONTROL
CODE ACQ COMMAND
CORRELATION VOLTAGE 0 TO +10V
RF INPUT
10 MHZ +10 DBM


CONTROL
LOOP
IN LOCK
NO LOCK
RELAY DRIVER
40 HZ
50 HZ
200 HZ
700 HZ
PHASE LOCK LOOP BANDWIDTH
STATIC PHASE ERROR
MON LEVEL
PHONES
AGC/MGC VOLTS
CAD VOLTS
+1.0 VDC (AGC)
MGC
MON AMPL
MONITOR
NOM SHORT
SHORT
OPERATE
LOOP FILTER
VCO CONTROL
NARROW
MEDIUM
WIDE
AGC BANDWIDTH
A4
DS4 CCS LOW GAIN
10 MHZ (LINEAR) -22 DBM (AGC)
10 MHZ (LIMITED) +4 DBM
10 MHZ NB AMPL (TLM) 3A1A10
CAPACITORS 3A1A15 3A1A19
K_D = 3500MV/DEG
10 MHZ PHASE DETECTOR (APC) 3A1A6
LOOP FILTER 3A1A12
ISO AMPL 3A1A17
0 TO 10 V
SPE
TEST RECEIVER SPE
P/O J30
DVM OSCILLOSCOPE
ISO AMPL 3A1A16
DPE
TEST RECEIVER DPE
OSCILLOSCOPE RMS VTVM
23 MHZ VCO 3A1A13
K_V = 400 C/V
23 MHZ +13 DBM
X4 MULT 3A1A14
23 MHZ 0 DBM
(CENTER FREQUENCY = 23.255208 MHZ)
TEST RECEIVER VCO
J9
COUNTER
50 MHZ IF OUTPUT
J8
SPECTRUM ANALYZER
0 TO 10 V
TEST RECEIVER AGC
TO MOD. CONT J5
DVM
ISO AMPL 3A1A18
TEST RECEIVER REF OSC 20.00000 MHZ
J5
COUNTER
J6
10 MHZ REF +10 DBM

REVISIONS			
LTR	DESCRIPTION	DATE	APPVD
X_3	REVISED PER MARKED PRINT	7 JULY 66	MCO A8745

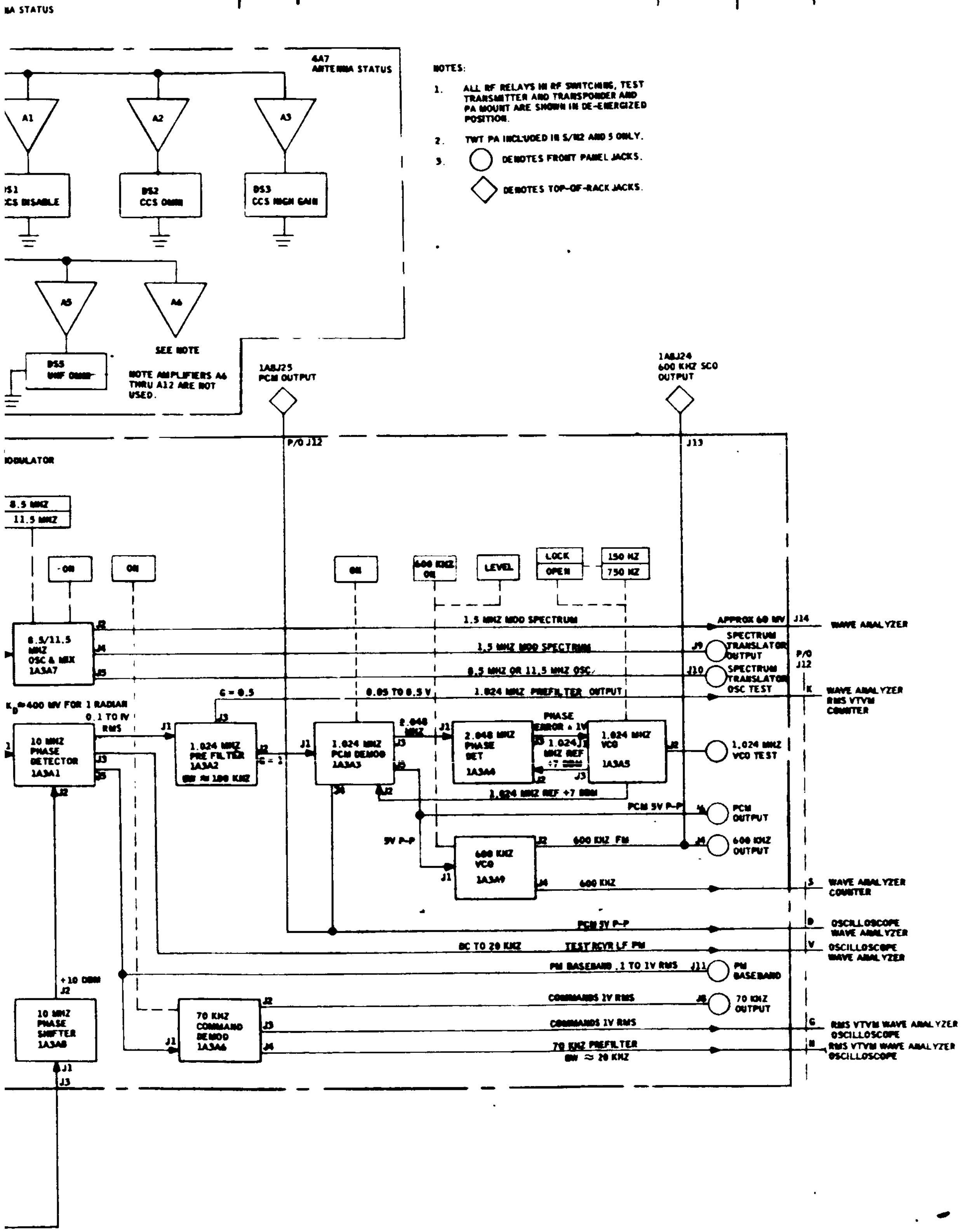


Figure 3-1. Command and Communication System Test Set, Block Diagram

Transponder and consequently their accuracy exceeds that of the transponder. The PN Coder/Decoder develops the necessary code and decode functions to enable the ranging function.

3.5.6 RF Switching Drawer

The RF Switching Subsystem is contained in an r-f tight drawer. It selects the mode of operation of the Test Set, determines the inputs to r-f power monitoring equipments and the Test Receiver. This unit also contains the r-f converter function used in SELF TEST.

3.5.7 Switching Drawers

The Switching I drawer is an interface panel for connecting signals to the RMS Voltmeter, Wave Analyzer, and Frequency Counter. Switching II drawer is an interface panel for connecting signals to the Spectrum Analyzer, 561A Oscilloscope, and the 545B Oscilloscope. Switching III drawer is an interface panel for connecting voltages to the Digital Voltmeter.

3.6 TEST SET ELECTRICAL CHARACTERISTICS

Characteristic	Description
Test Set Power Requirement	
Type	110-120 VAC, 60 Hz, single phase
Power Input	Approx. 30 amps
Test Transmitter/Test Receiver Characteristics	
Phase Jitter	7° rms maximum in a 40 Hz loop
RF Path Accuracy	±2 db maximum, ±1 db design goal
Test Receiver Subsystem Characteristics	
System Inputs	
Center Frequency	2282.5 MHz
Coherent Tuning Range	±244 kHz (using internal VCO)
Non-coherent Tuning Range	2270 to 2280 MHz (using an external VCO)
Signal Level (nominal)	-60 to -150 dbm (at preselector input)
Variable Attenuator Range	0 to 120 db

Test Receiver Subsystem Internal Characteristics

Voltage Controlled Oscillator	
Center Frequency	23.255208 MHz
Tuning Capability	±244 kHz minimum (at S-band about center frequency
VCO Sensitivity (Kv)	Approx. 400 Hz/volt
Long Term Stability	Approx. 1 x 10^{-6}/10 hours
Predetection Filter	
-3 db bandwidth	6.3 kHz nominal
Noise bandwidth	10 kHz nominal
Automatic Phase Control Loops and Thresholds	
Type	Adaptive, passive
Strong Signal Bandwidths	40 Hz nominal

Threshold Bandwidths	Level
50 Hz	-145.5 dbm
200 Hz	-139.4 dbm
700 Hz	-133.4 dbm

Strong Signal Loop Gain	Approx. 5 x 10^6
Weak Signal Noise Figure	10 db max. (referenced to preselector input)
Reference Oscillator	
Frequency	20 MHz ±20 Hz
Visual and Aural Aids to Lock	
Aural	Speaker/Headphones to DPE
Visual	1. Oscilloscope on DPE 2. Panel meter and digital VTVM indications of SPE, CAD, and AGC 3. Lamp Indicator (from AGC/MGC)

Doppler Tracking Rate

Threshold BW $2B_{LO}$	Phase Error (degree peak)	Strong Signal Min. Doppler Rate (Hz/sec)
50^{+0}_{-20}%	30	1,500
200^{+0}_{-20}%	30	12,000
700^{+20}_{-0}%	30	115,000

AGC Characteristics

AGC Bandwidth Position	Time-Constant (seconds)	Loop Bandwidth (Hz)
Narrow	150	0.16 ±0.04
Medium	15	1.6 ±0.4
Wide	4.0	6.0 ±1.5

RF Signal Level Dynamic Range	-60 to -150 dbm minimum
Static Gain Stability (as strong signal)	0.4 db max/10 hours
MGC Control Range	-60 to -150 dbm minimum

Receiver Subsystem Outputs

10 MHz IF Signal to Ranging Receiver

Level	-65 ±3 dbm (with AGC operating)
Bandwidth	±5.5 MHz minimum ±8 MHz

10 MHz Reference to Ranging Receiver

Level	+10 dbm ±3 db

10 MHz IF Signal to Demodulator

Level (limited channel)	+4 dbm nominal
Level (linear channel)	-32 dbm to +8 dbm

AGC/MGC Voltage (to Modulation Control Drawer)	
Level	0 to -10 volts
<u>Monitor Outputs</u>	
20 MHz Reference Oscillator	
Frequency	20 MHz
Level	+1.5 dbm ±1.5 db
VCO Monitor	
Frequency	23 MHz nominal
Level	0 ±3 dbm
50 MHz Spectrum	
Frequency	50 MHz nominal
Level	40 db above input signal level (nominal)
AGC/MGC Voltage Level	0 to -10 volts
<u>Demodulator Drawer Characteristics</u>	
Inputs	
10 MHz Phase Detector Input (signal)	+4 dbm ±1 db
10 MHz Phase Detector Input (reference)	+10 dbm ±3 db
10 MHz Spectrum Input	-22 dbm nominal -12 dbm max. for linear operation
Input Bandwidth	3 MHz minimum
70 kHz Subcarrier on 10 MHz	
Type of Modulation on 10 MHz	Phase
Type of Modulation on 70 kHz	Frequency
1.024 MHz Subcarrier on 10 MHz	
Type of Modulation on 10 MHz	Phase
Type of Modulation on 1.024 MHz	Bi-phase

Demodulator Drawer Internal Characteristics

10 MHz Detector	
Type	Phase
Output Level (W.B.)	(Kd) x (Sine of Mod. Index) where Kd is approx. 10 mv/°
DC Bandwidth (W.B.)	DC to 1.5 MHz
70 kHz Demodulator	
Type	FM (Pulse-counting)
Carrier Frequency	70 ±1 kHz
Predetection -3 db Bandwidth	20 ±5 kHz
Input Level	0.1 to 1.0 VRMS
1.024 MHz Demodulator	
Type	PM with Phase-Lock Loop
Predetection -3 db Bandwidth	160 kHz ±10%
Carrier Frequency	1.024 MHz ±50 Hz
Maximum Information Rate	72 Kilobits/sec.
Loop Bandwidth, $2B_L$	750 Hz, 150 Hz
Spectrum Translator	
Input Level for Linear Output	-22 dbm maximum

Demodulator Drawer Outputs

10 MHz PM Demodulator	
Wideband Output (Front Panel)	High Z Load only
L.F. Output Bandwidth	100 Hz to 10 KHz
70 KHz Pre-filter output level	approx. 6 db below input
70 KHz Demodulator Outputs	
Number	Two
Level (95 ohm load)	1V RMS for 5 KHz peak dev.
Bandwidth (-3 db)	100 Hz to 4 KHz minimum
Phase Linearity	700 - 4000 Hz, within ± 20 μsec
	300 - 700 Hz within ± 120 μ sec
10 MHz Prefilter output level	Approx. 6 db below input
1.024 MHz Demodulator Outputs (2)	
Level	5V p-p
Frequency	Limited by Prefilter
Logic	Ambiguous
VCO Test Level	+4 dbm nominal
Modulation Spectrum	
Level	1 VRMS maximum
Bandwidth	2 MHz minimum
600 KHz Modulator	
Type	FM by PCM Output
Center Frequency	600 KHz
Deviation (by PCM)	36 ± 6 KHz peak
Linear Range of Deviation	to 54 KHz peak
Output Level (into 950 ohms)	1 VRMS to 2.5 VRMS

Modulation Control Drawer Characteristics

Drawer Inputs:

Command Modulation on 70 KHz

Level:	5V p-p maximum
Bandwidth:	DC to 10 KHz

PCM Modulation Input

Level:	10 V p-p nominal

Square Wave Generator

(internally generated)

Frequency (Front Panel Adjust):	50 Hz to 36 KHz minimum

PRN

Level:	4 V p-p maximum
Bandwidth (-3 db)	DC to 2 MHz

Sweep

Level:	15 V p-p maximum
Frequency	DC to 10 Hz

Drawer Outputs

Composite PM and Monitor

Output Level:	5V p-p maximum
Bandwidth:	DC to 2 MHz, minimum

VCO Control and Monitor

Level:	± 6.5 volts
Bandwidth:	DC to 10 Hz

Monitor Outputs

Circuits	PCM Input, command modulator Input, 70 KHz SCO Output, 1.024 MHz modulator output, sweep output

Sweep Drive (to HP 3300A)

Frequency (Front Panel Adjust)	0 to -10 VDC

(The input to the HP 3300A function generator is normally disconnected at the rear of the HP 3300A. This allows the HP 3300A dial only to control the frequency. When the frequency of the HP 3300A is to be remotely adjusted by the Modulation Control Drawer, remove shorting bar from rear terminals of the HP 3300A and attach cable 2W42 to the HP 3300A.

Transmitter Drawer Characteristics

Drawer Inputs:

Phase Modulator Input

Frequency	DC to 2.0 MHz
Modulation Capability	0 to 3 radians minimum

Frequency Modulator Input

Frequency (sweep rate)	0 to 100 Hz minimum
Level	0 to ± 6.5 V DC nominal

External Oscillator Input

Frequency	approx. 22 MHz, or 1/96 of output frequency
Level	+10 dbm +6 - 0 db

Drawer Outputs:

VCO Frequency Output (to counter)

Frequency	22 MHz approx. or 1/96 of S-Band output frequency
Level	0 dbm ± 3 db

VCO Ranging Reference Output

Frequency	22 MHz approx., or 1/96 S-Band output
Level	10 dbm ± 3 db

S-Band Outputs

Nominal Frequency	2101.802 MHz (provided by the internal VCO
Tuning Range	± 222 KHz minimum about nominal center frequency
RF Bandwidth (external VCO)	Flat to within 1 db at ± 5 MHz
Residual AM	± 1 db maximum when phase Modulated to 3 radians
Power Meter Output Level	+5 dbm ± 4 db
Spectrum Analyzer Output Level	-25 dbm ± 5 db
RF Switching Drawer Low Level	Variable -8 dbm maximum to -170 dbm minimum. Settable ± 1 db, calibrated to within ± 2 db
TWT Amplifier Output	Variable +13 dbm to -107 dbm

RF Switching Drawer Characteristics

SELF TEST Mode:

Input signal (J9)	
Frequency	2101.8 MHz ±220 kHz
Level	-10 to -160 dbm
Output Signal #1 (J5)	
Frequency	2282.5 MHz nominal
(Input signal frequency	+180.698 MHz)
Conversion Loss (with -10 dbm input)	36 db maximum
Output Signal #2 (J4)	10 db below #1 output
Output Signal #3 (J8)	
Frequency	45.174500 MHz ± 150 Hz
Level into 50 ohms	+10 dbm nominal

Bench Transponder Mode:

Input to output insertion losses at	2282.5 MHz
J9 to J10	2 db nominal
J14 to J5	60 db nominal
J14 to J4	70 db nominal

Bench Power Amplifier Mode:

Input to output insertion losses at	2282.5 MHz
J9 to J10	0 db nominal
J14 to J5	60 db nominal
J14 to J4	70 db nominal

VAB Mode:

Input to output insertion losses at 2282.5 MHz

J13 to J5	40 db
J13 to J4	50 db

PAD Mode:

Input to output insertion losses

J11 to J12	1.5 db max. at 2102 MHz
J12 to J4	1.0 db max. at 2282 MHz

Power Monitor Meter Zero Set

(Depress METER ZERO SET switch)

Input to output insertion losses at 2102 MHz

J7 to J6	2 db maximum

Power Monitor Transmitter Out

(Depress XMTR OUTPUT switch)

Input to output insertion losses at 2102 MHz

J7 to J6	0 db nominal

Power Monitor Bench Downlink

Bench Transponder RF power output

(Depress both BENCH XPNDR and BENCH DOWN LINK switches)

Input to output insertion at 2282 MHz

J14 to J6	2 db maximum

Power Monitor VAB Downlink

VAB downlink RF power

(Depress both VAB and VAB DOWNLINK switches)

Input to output insertion losses at 2282 MHz

J13 to J6	2 db maximum

Power Monitor Pad Uplink

PAD uplink RF power output

(Depress PAD UPLINK switch)

Input to output insertion losses at 2102 MHz

J11 to J6	41 db nominal

Ranging Subsystem

Type:	Uses a pseudo-random noise ranging code with direct delay readout in nanoseconds, for delay less than 1 millisecond, and readouts in bits and nanoseconds for longer delays.
Code:	A LUNAR code of 2,728,341 bits and a SATELLITE code of 35,805 bits - identical to the JPL Mark I Ranging Codes. Maximum unambiguous range of LUNAR Code; 513,000 miles. Maximum unambiguous range of Range Delay Counter: 999,999 NS (approx. 100 miles)
Code Acquisition Automatic	1. Rate of search: 0.5 seconds per bit 2. Range of search: 15 bits over any preset range from 0 to 999 bits. 3. Indication of acquisition: automatic when correlation exceeds 62.5%.

Code Acquisition: Manual	1. Type of acquisition: full code or by sub-codes 2. Indication of acquisition: visual indication of correlation
Correlation Detection:	absolute level of correlation voltage in automatic mode, relative levels in manual mode.
Resolution:	± 1 nanosecond
Accuracy:	Dependent on input signal (clock power) to noise ratio and the sampling period selected.

Ranging Receiver

General Type:	automatic phase lock automatic gain control static offset frequency (zero doppler)
Dynamic Range:	Exceeds 40 db (PRN sideband power greater than -65 dbm to less than -105 dbm)
Clock Frequency Range:	495.334 KHz ± 25 Hz
Delay Stability:	± 2 nanoseconds due to frequency offset 5 nanoseconds max. for PRN sideband power between -70 dbm and -100 dbm. 10 nanoseconds maximum for ambient temperature variation of 30°F

AGC Loop Gain:	30 db/db minimum
Clock Phase Tracking Loop Noise Bandwidth:	2 Hz nominal

Transponder and PA Control Drawer Characteristics

No signals are generated within the Transponder and PA Control Drawer. One subassembly serves as a lamp driver and a single-ended to double-ended PCM driver. A second subassembly contains 10 relays for voltage monitoring. The power and telemetry signals controlled by this drawer provide operating power and monitor outputs for the Transponder and Power Amplifier under test.

Transponder and PA Mount Drawer Characteristics

No signals are generated by the Transponder and PA Mount Drawer.

Switching I, II, and III Drawer Characteristics

The signals to be monitored on the three switching panels are selected by the individual pushbutton switches on each drawer. Each drawer contains several subassemblies containg 10 relays for voltage monitoring.

TWT Power Amplifier Characteristics

(Included only in Test Sets S/N 2 and 5)

Procurement specification	Motorola No. 12-21510H, Issue X4
Saturated Power Output	+43 dbm (20 watts)
Saturated Power Gain	+33 db minimum
Noise Figure	+35 db maximum
Center Frequency	2101.8 MHz

SECTION IV

4.0 ADDITIONAL TEST DATA

Many measurements were made on CCS Transponder S/N 2, using the CCS Test Set. Some of those tests were performed in the course of the acceptance tests performed on some or all of the Test Sets. Other tests were performed on one or more Test Sets, primarily to assure us that the Test Set would perform the functions of testing the transponder in an accurate manner. Some of the later set of tests (those not in normal acceptance tests on the Test Set) are described here.

4.1 SIGNAL-TO-NOISE RATIO OF 70 kHz DEMODULATOR

Figure 4-1 shows the signal-to-noise output of the 70 kHz Demodulator in the Test Set vs. signal level into the Test Receiver. This curve marked and Table IV-1 give the pertinent parameters. (This data was taken from the acceptance tests on Test Set S/N 4.)

The curve marked on Figure 4-1 is the signal-to-noise out of the 70 kHz (Command) Demodulator in the transponder. Note that this curve is approximately 2 db worse than that out of the Test Set 70 kHz Demodulator (at weak signals), which is the difference in noise figures of the two receivers. This proves that the Test Set 70 kHz Demodulator performs in a manner quantitatively similar to the Command Demodulator in the transponder.

The third curve of Figure 4-1 that is marked , was taken in a different manner than normally done. The Test Transmitter was modulated with a 70 kHz subcarrier. This subcarrier was turned around in the transponder through the ranging channel, modulating the downlink with the 70 kHz signal and noise. The 70 kHz subcarrier was demodulated in the Test Receiver, and the signal-to-noise out of this demodulator was measured as the transponder receiver input signal was reduced. The downlink signal into the Test Receiver was kept

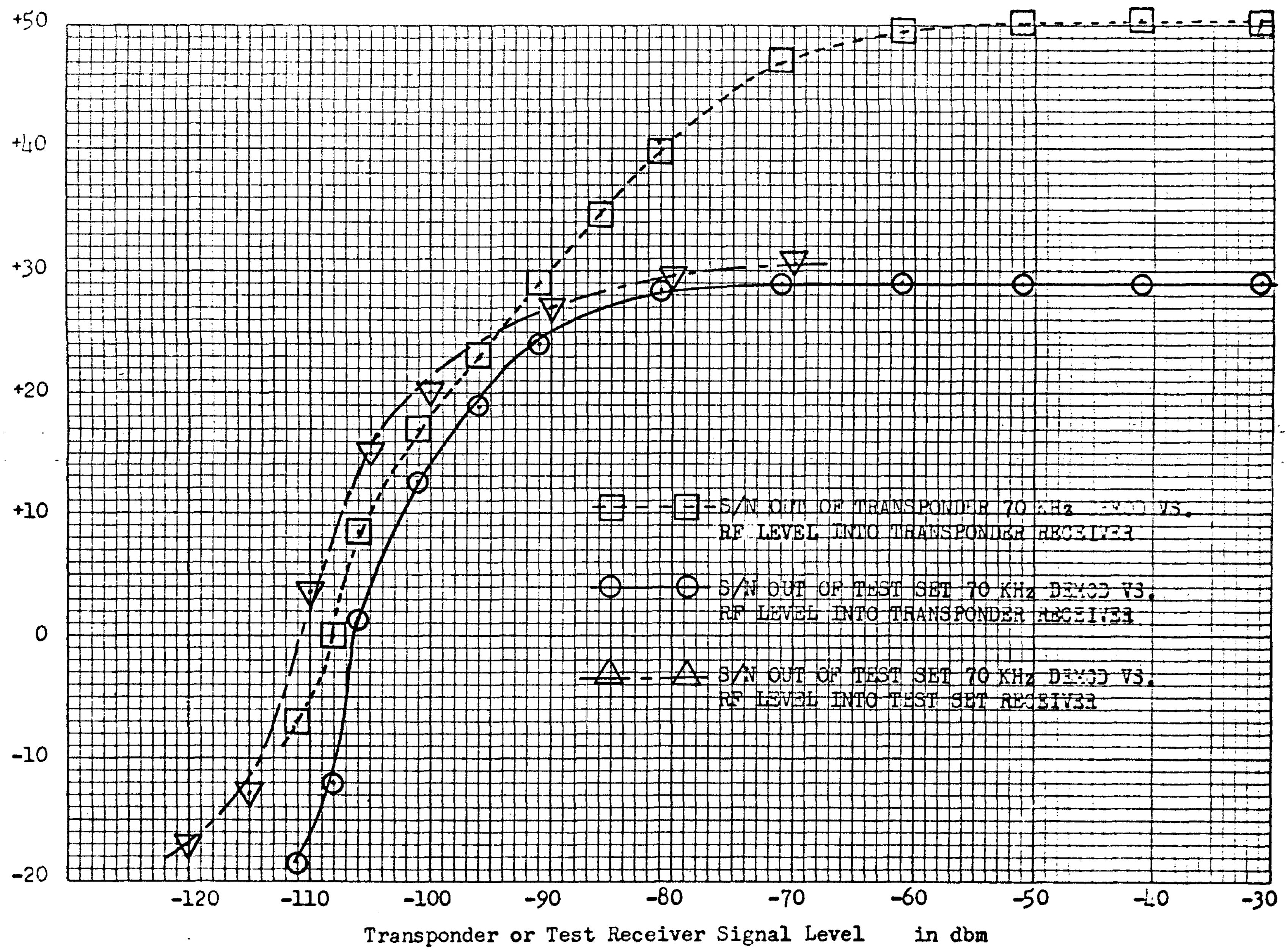


Figure 4-1.

S/N Out of 70 KHz Demodulator Vs. Received Signal Level into Test Receiver or Transponder strong (approximately -70 dbm). The explanation of why this curve did not agree identically with that out of the transponder 70 kHz demodulator is beyond the scope of this report.

Table IV-1.
Conditions for Figure 4-1.

Curve	Modulation on the 70 kHz Subcarrier	Demodulator Used	Transponder Noise Figure	Test Receiver Noise Figure	Modulation Index of 70 kHz
▽ - - ▽	2 kHz sine wave at 5 kHz peak deviation	Test Set	N/A	8.5 db	1.2 radians peak
-⊟- - -⊟-		Transponder	10.5 db	N/A	1.2 radians peak
○——○		Test Set	10.5 db	8.5 db	1.2 radians peak up 1.16 radians peak down

4.2 COMMAND CHANNEL PHASE RESPONSE

The Test Set 70 kHz Demodulator was designed to be essentially the same as the Command Demodulator in the transponder. There is one difference, however: the output filter in the Test Set 70 kHz Demodulator was designed to have flatter phase response than the corresponding filter in the transponder. This agreed with the philosophy that the Test Set should be the same electrically as the corresponding circuit in the transponder, but the test circuit should be quantitatively better so it can be used to test the transponder.

Phase response, or time delay, which is really the important parameter, was measured on all 70 kHz Demodulators as part of the drawer tests on the demodulator. The results of one of these is plotted on Figure 4-2.

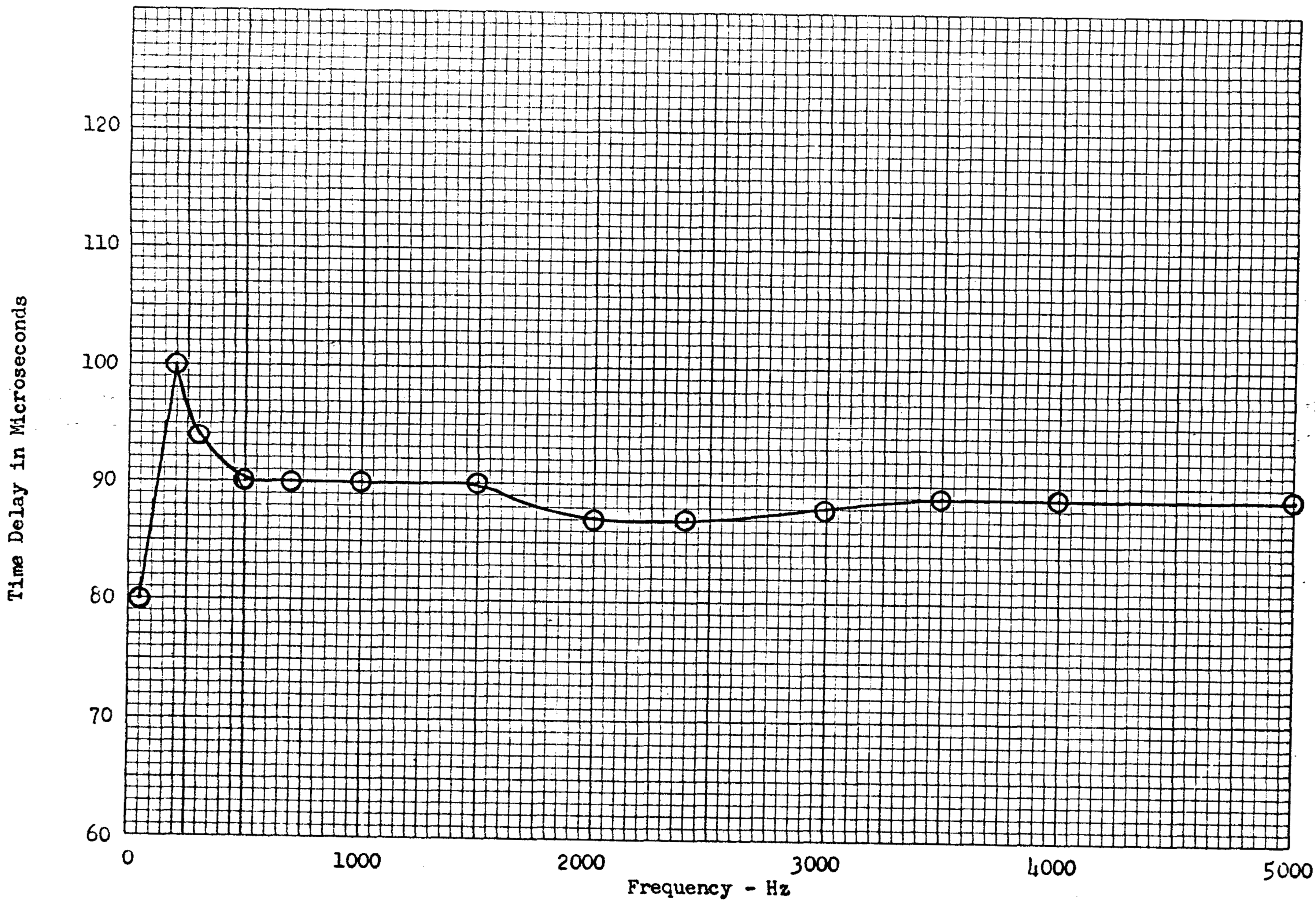


Figure 4-2. Command Channel Time Delay

4.3 TRANSPONDER RANGING DELAY

Using the CCS Test Set, the ranging delay of a CCS Transponder can be easily determined. This was done on CCS Transponder S/N 2 using several Test Sets.

a. Ranging Delay as Uplink Signal Level is Changed

The transponder suppresses the turn-around ranging power (the ranging power into the ranging receiver) when the r-f signal into the transponder receiver is reduced. This effect is shown in Figure 4-3. (See Reference 1.)

Because of this turn-around suppression, the ranging rcvr. is required to be able to operate over a wide ranging power. For this reason, a ranging delay vs. ranging power test is performed on each Test Set in the SELF TEST mode. These results are plotted on Figure 4-4 for three different Test Sets, but in a manner modified from the original data. Figure 4-4 converts "reduction in ranging power, in db" to "Received Signal Level into S/N 2 CCS Transponder, for 0.6 Radians Modulation on Uplink".

Part of each of these curves are due to the Ranging Receiver operating in noise, and part of the curve due to the method in which the test was conducted. For this test, the modulation index of the ranging was changed to simulate a reduction in ranging power on the downlink by the Transponder Receiver suppression. However, the modulation index was changed by adjusting a pot on the modulation control drawer. As the pot is adjusted, the upper frequency is changed, which changes the time delay. Our experience has been that the change in time

Reference 1. Pages 103-105, "Electronic Systems Test Program Final Report CCS Transponder/MSFN for Compatibility and Performance Evaluation", Information Systems Division, NASA, Manned Spacecraft Center. Report CB-66-3302-U, 15 April 1966.

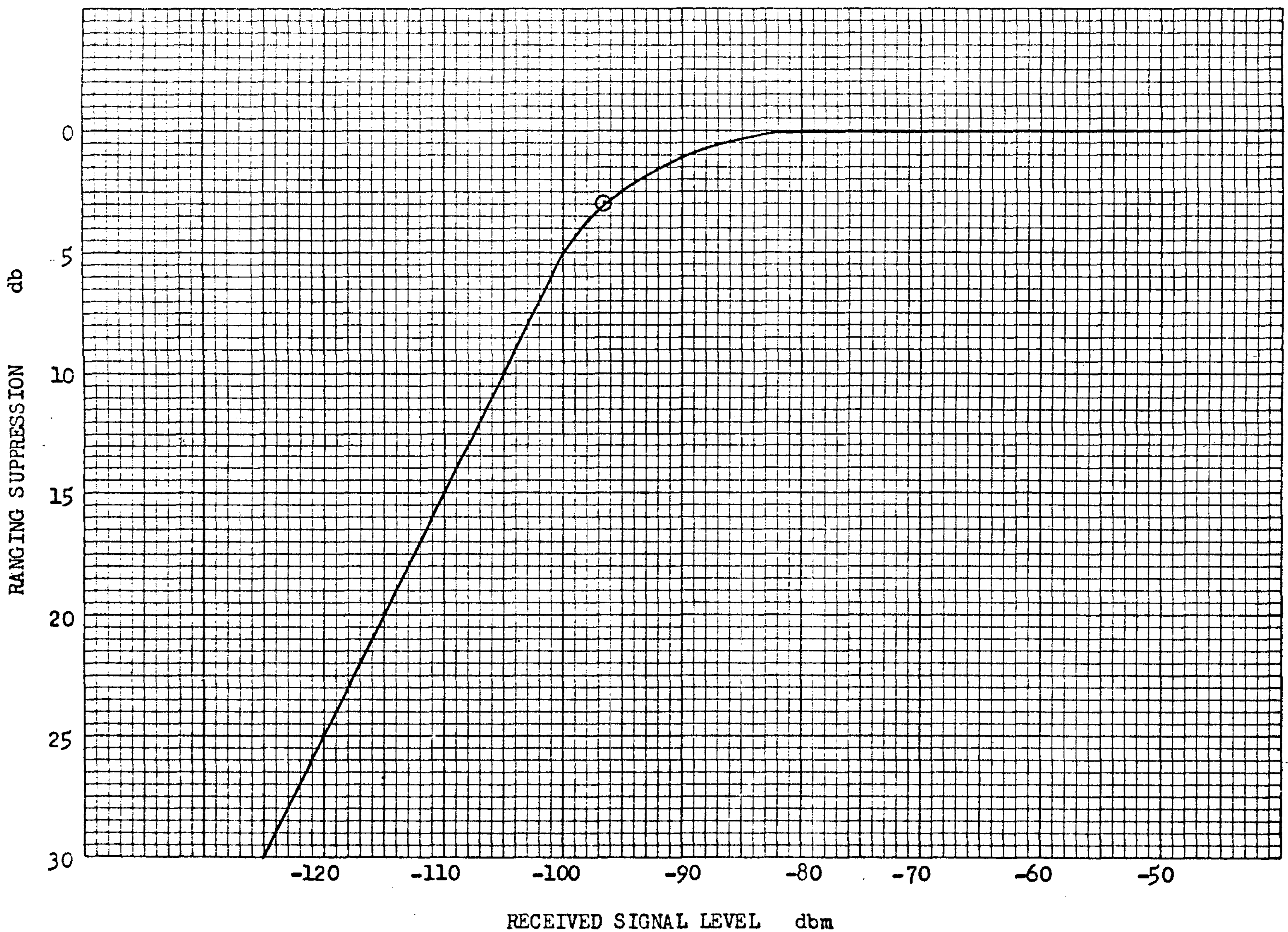


FIGURE 4-3.

RANGING SUPPRESSION OF CCS TRANSPONDER S/N 2

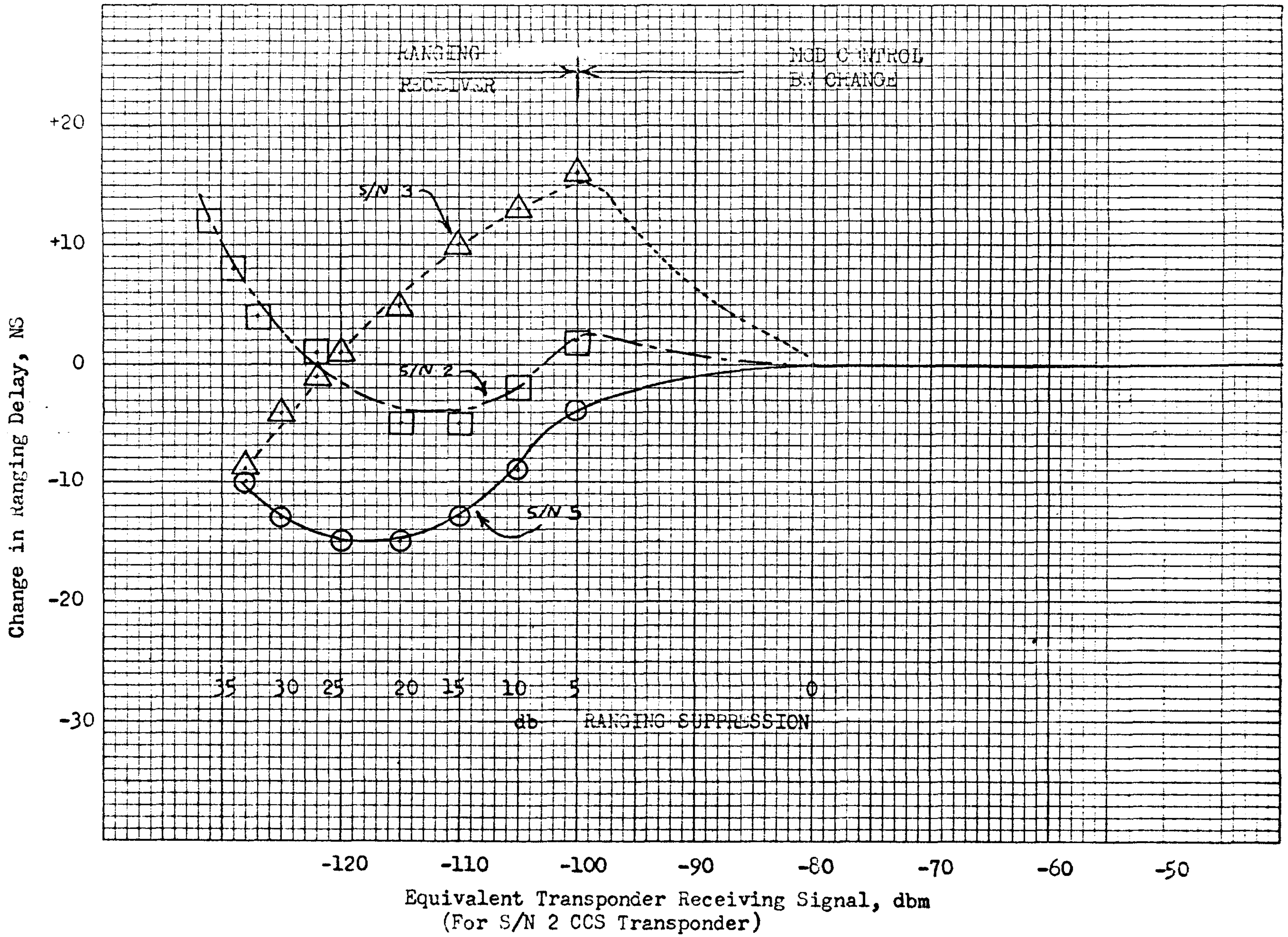


Figure 4-4.
Change in Delay Due To CCS Test Set

delay due to the modulation control is greatest at higher levels of modulation (modulation index). Hence, only the part of the curves to the left (lower signal levels) of -100 dbm, represent the real time delay change in the Ranging Receiver due to change in ranging modulation. This part represents a correction to total ranging delay of a transponder when measured in Test Set S/N 2. Applying the above correction gives the ranging delay just due to the transponder itself. Both the correction for S/N 2 Test Set and the corrected curve are shown in Figure 4-5.

b. Ranging Delay vs. Change in Carrier Frequency

Figure 4-6 shows the change in ranging delay through CCS Transponder, S/N 2 using Test Set S/N 5. Also, the change in delay through the Test Set itself (in the SELF TEST mode) is shown, as the frequency is changed. Keep in mind that there is only 1 ns resolution, so these curves are not too accurate. However, they do show that the change in delay through S/N 2 Transponder and the delay through the CCS Test Set is insignificant. For comparison purposes, the change in system delay through the modified DSIF Receiver-Exciter-Ranging Subsystem (S/N 3) with Apollo Block I CSM Transponder S/N E-2 is shown, at least in part (See Reference 2). It is not fair to make a direct comparison of those two curves. The second curve is shown to illustrate the effect of VCO loops in the Ranging Receiver. This shows the reason why this Test Set, designed to test a transponder, is more accurate than other devices that use the VCO loop method in the Ranging Receiver.

Reference 2. "Task I - Final Report, Apollo Unified S-Band System Block I Compatibility Test Program", Motorola, Inc., Report WF 2996-23, 8 September 1965.

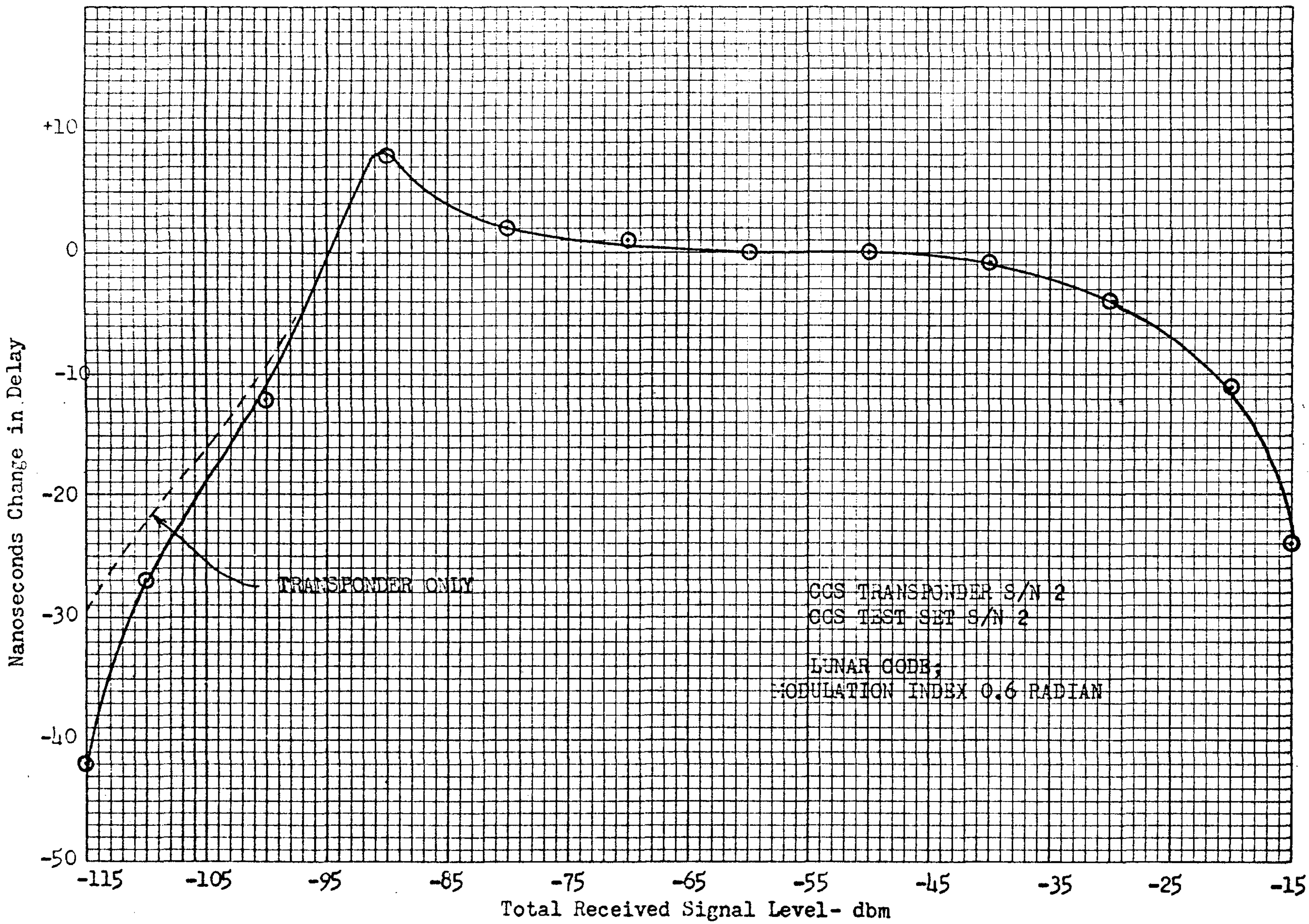


Figure 4-5.
Change in Ranging Delay Vs. Transponder Input Signal Level

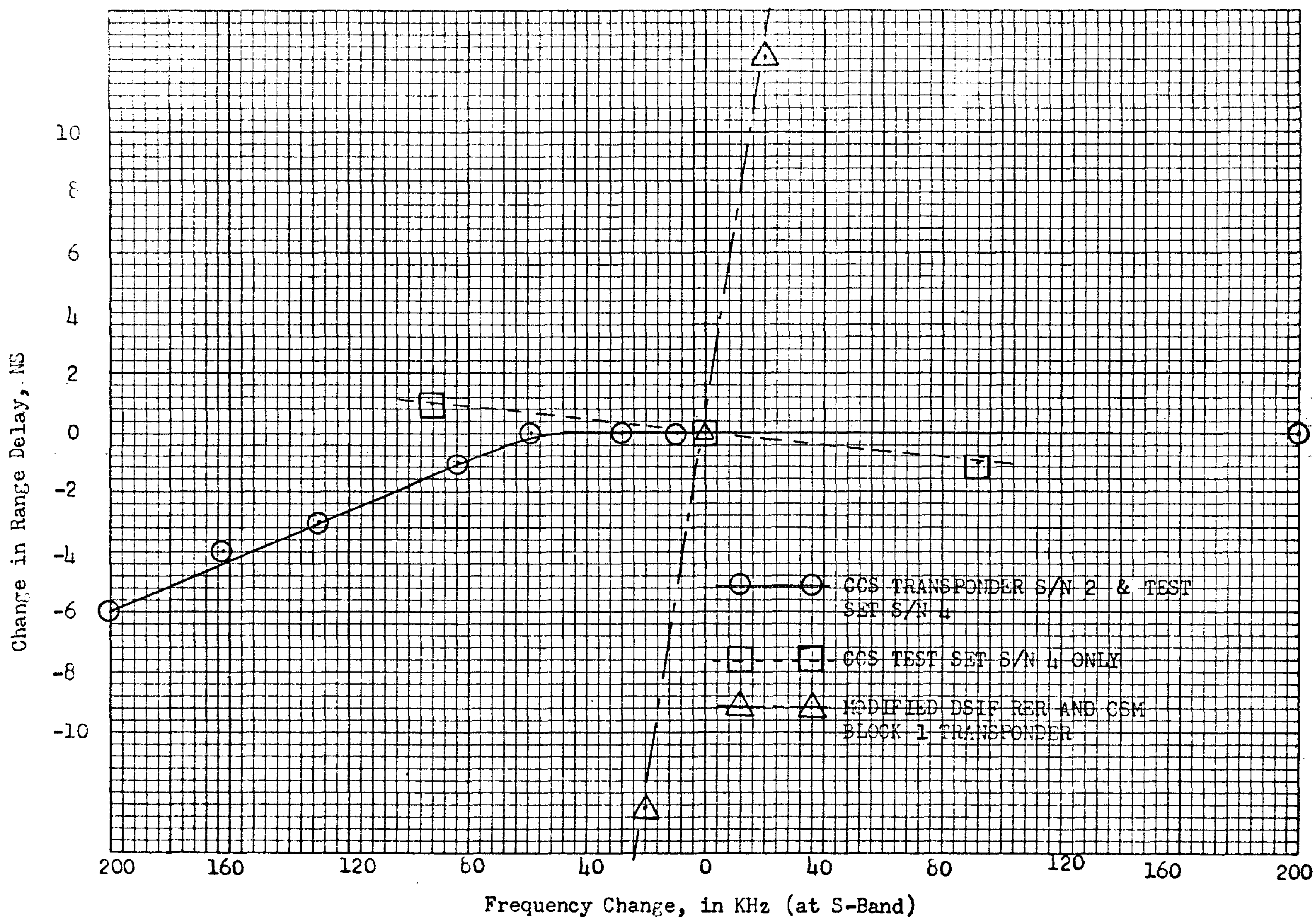


Figure 4-6.
Range Delay Vs. Up-Link Offset Frequency

SECTION V

5.0 RECOMMENDATIONS

The CCS Test Set represents a complete Test Set that meets the objectives for which it was designed. There are several things that could be done to improve its usefulness for MSFC.

5.1 IMPROVED STRONG SIGNAL PERFORMANCE OF THE TEST RECEIVER

The strong signal performance of the Test Receiver, being the same as the DSIF and MSFN Receivers, is limited by the signal-to-noise out of the receiver. This signal-to-noise ratio is limited because of the gain distribution of the receiver. Figure 5-1 shows the signal and an estimate of the noise at certain points of the Test Receiver. Some of these are estimates, and indeed, the critical noise contributing stages are not specified. However, a study of this figure indicates why the strong signal signal-to-noise ratio is not better than it is.

Shown on Figure 5-1 are attenuators "X". These attenuators do not exist in the present Test Set Receivers, but could be added quite easily. Tables V-1a and V-1b show the signal and noise at various points for X = 0 and for each X = 20 db, respectively. For the present Test Receiver, the output signal-to-noise ratio is -12 db for a noise bandwidth of 4 MHz, which is approximately the two-sided noise bandwidth of the PM output. For X = 20 db, this signal-to-noise increases to +8 db, for an improvement of 20 db.

There is a penalty one must pay for this strong signal improvement in signal-to-noise - the threshold performance of the test receiver may suffer. The receiver was designed to be used in the DSIF System of JPL, where thresholds of lower than -170 dbm were specified (using a traveling wave maser). At this signal level, the i-f amplifier must have 50 db gain for X = 0 and 70 db gain for X = 20 db. The AGC'd amplifier part of this module is not capable of 70 db

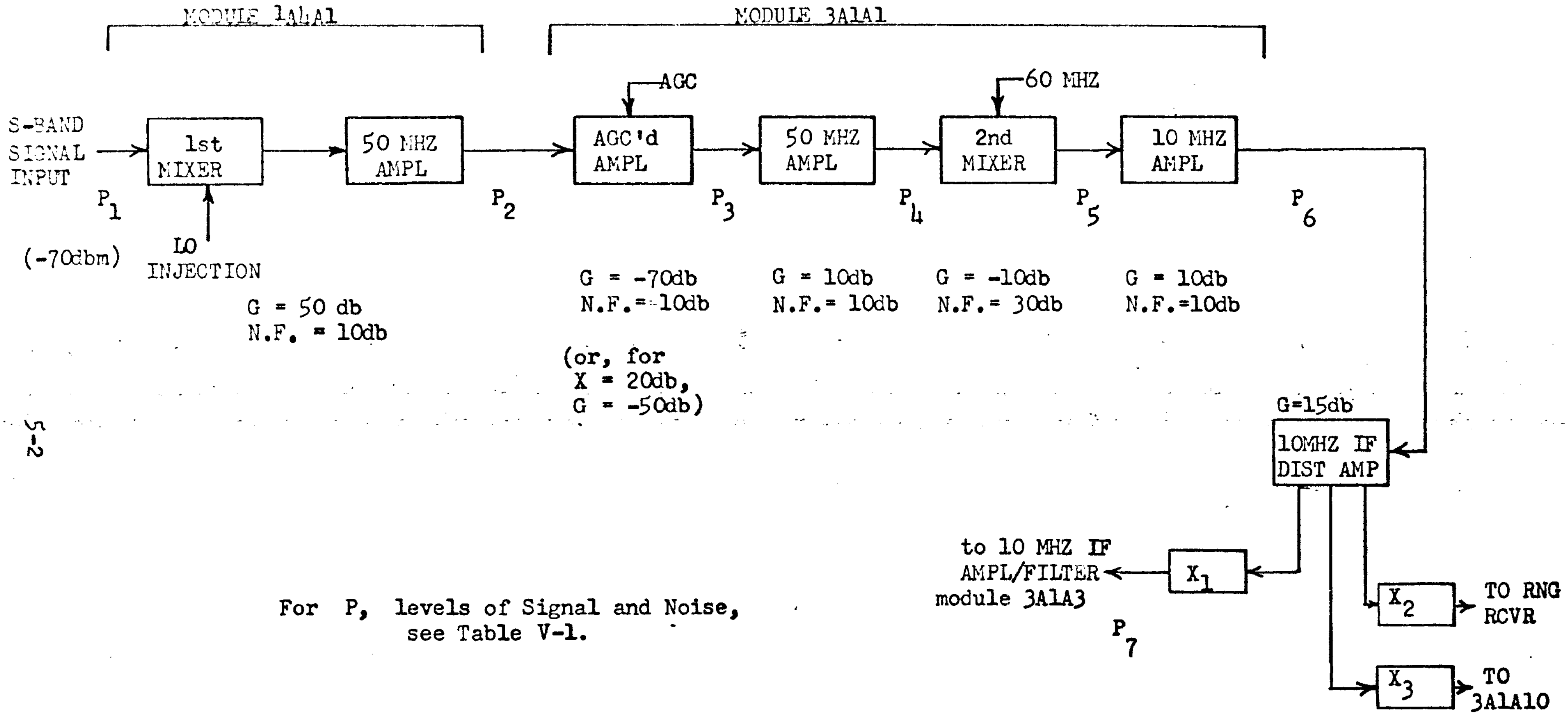


FIGURE 5-1.

SIGNAL DISTRIBUTION OF TEST RECEIVER

gain. For the MSFN System, signal levels can go to about -158 dbm. For this Test Set, signals can go to about -150 dbm. The i-f amplifier probably has adequate gain for -150 dbm, if X = 20 db.

Signal levels at other parts of the Test Set will be incorrect if this 20 db pad is added. For instance, the level to the ranging will be -45 dbm, instead of the -65 dbm required. Also, the level to the 10 MHz narrowband amplifier, 3A1A10, should also be reduced to -65 dbm. These corrections are made by adding X_2 and X_3, also 20 db.

5.2 MODIFICATIONS TO ALLOW MORE COMPLETE INVESTIGATION FOR COMMAND CHANNEL

The 70 kHz Demodulator in the Test Set, and that in the Transponder, can be quantitatively checked by measuring signal-to-noise output. This does not give a complete picture of the performance of the command channel, however, the method that MSFC has used was to correct the command decoder and measure message reject rate. With slight modification, the CCS Test Set could be made to measure sub-bit error rate and/or message reject rate. A scheme to do this is shown on Figure 5-2.

The blocks shown in solid lines on the right part of Figure 5-2 would be needed to determine sub-bit error rate (SBER). Errors would be counted on an events counter. (The HP-5245L, installed in the Test Sets, can be used without modification.)

Since the sub-bit rate is 1 kb/s, bits transmitted can be determined either with an events counter, or a watch. The detector should be identical electrically to that in the command demodulator.

The blocks shown in dashed lines represent that which would be added if message acceptance pulses (MAP) and message reject pulses are to be counted. Message reject rate is messages rejected per messages sent.

Table V-1a

Signal and Noise Levels
CCS Test Receiver As Is

Symbol	Point	Sig. Level dbm	N_A dbm/cy	N_B dbm/cy	NBW MHz	Total Noise Power dbm	S/N db
P_1	S-Band Input	-70	- -	-164 (referred to input)	10	-94	+24
P_2	Input to AGC'd Amp	-20	- -	-114	10	-44	+24
P_3	Output of AGC'd amp	-90	-184	-164	10	-94	+4
P_4	Input to Mixer	-80	-154	-164	10	-84	+4
P_5	Output of Mixer	-90	-164	-144	10	-74	-16
P_6	10 MHz Output	-80	-134	-164	10	-64	-16
P_6	10 MHz Output	-80	-134	-164	4	-68	-12
P_7	Input to 10 MHz Amp/Filter	-65	-119	-164	4	-53	-12

Table V-1b

Signal and Noise Levels
CCS Test Receiver with X_1, X_2, and X_3 = 20 db

Symbol	Point	Sig. Level dbm	N_A dbm/cy	N_B dbm/cy	NBW MHz	Total Noise Power dbm	S/N db
P_1	S-Band Input	-70	- -	-164 (referred to input)	10	-94	+24
P_2	Input to AGC'd Amp	-20	- -	-114	10	-24	+24
P_3	Output of AGC'd Amp	-70	-164	-164	10	-91	+21
P_4	Input to Mixer	-60	-151	-164	10	-81	+21
P_5	Output of Mixer	-70	-161	-144	10	-74	+4
P_6	10 MHz Output	-60	-134	-164	10	-64	+4
P_6	10 MHz Output	-60	-134	-164	4	-68	+8
P_7	Input to 10 MHz Amp/Filter	-65	-139	-164	4	-73	+8

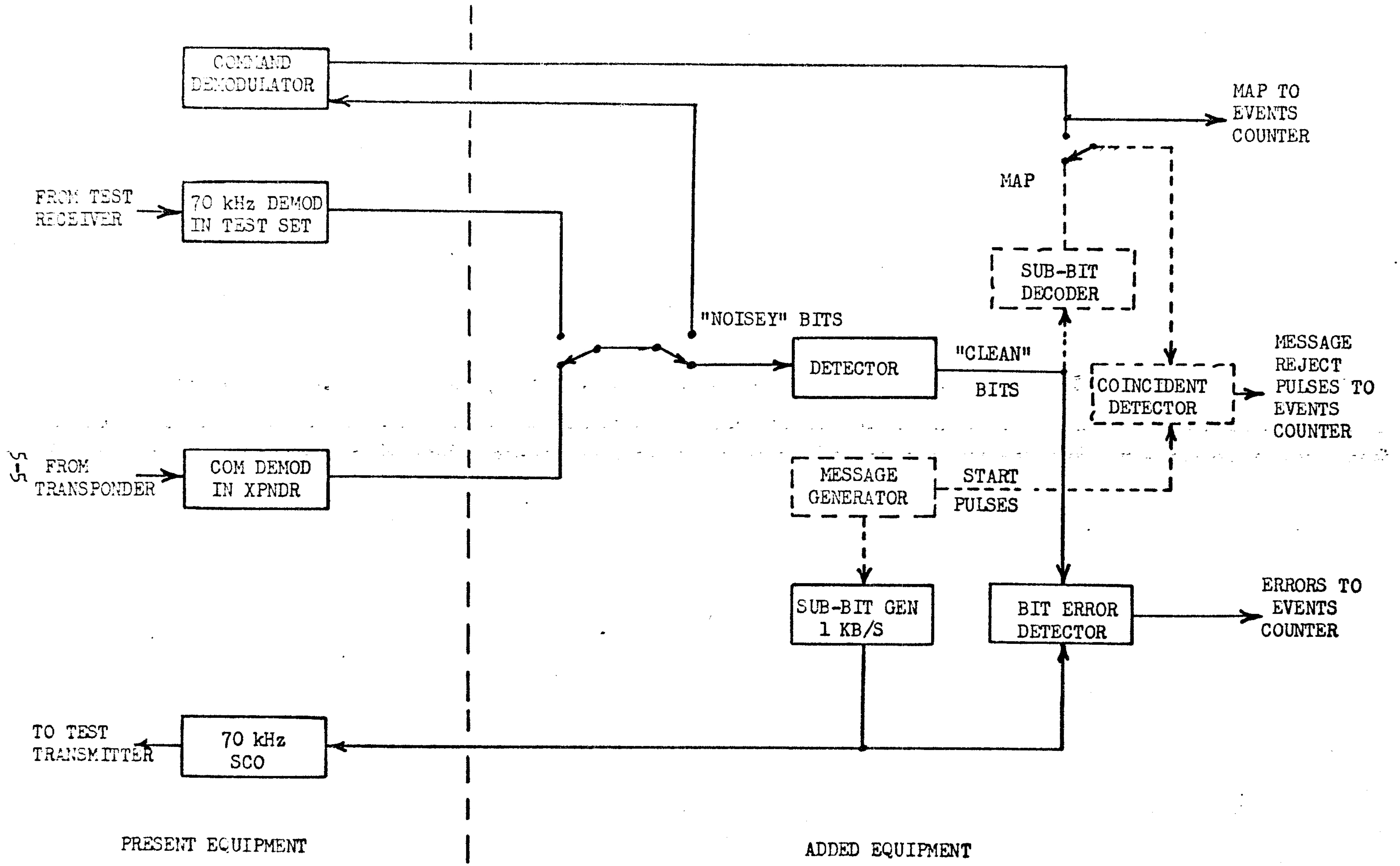


Figure 5-2. Modifications for Command Channel Investigation

If improvements to either the command demodulator or the sub-bit demodulator are to be made, then this scheme or an equivalent is necessary. Also, this scheme will allow a more complete checkout of the command system.

5.3 RANGING SELF-CHECK FEATURE

After the Ranging Subsystem was designed, and during the system check-out, a very useful test was performed on the Range Delay Counter and PN Coder/Decoder. This test consisted of a Self-check of these two drawers. The purpose of this set of tests is as follows:

1. Give confidence that the Range Delay Counter and PN Coder/Decoder are working properly.
2. Greatly simplifies troubleshooting of the Ranging Subsystem.

It is recommended that the PN Coder/Decoder and the Range Delay Counter be modified as described below.

This retrofit will require the addition of a PC card in the Coder Bay assembly, a 1 MHz amplifier in the Range Delay Counter, three coax relays in the coder and associated bay, drawer and drawer interface wiring. The SELF TEST logic is shown in Figure 5-3. A normal-test switch will be added to the rear bulkhead of the Coder. This switch, when set in the test mode, will enable three coax relays which in turn switch the Coder's T_X C_L, R_X C_L and C_L inputs from the ranging receiver to the internal clock generator. The normal-test switch will also enable a correlation-voltage generator and a test indicator light when the switch is set to the test mode. The Coder's auto acquisition start switch-light will be converted into a start switch-light and self-test indicator. The self-test indicator will be enabled when the Coder/Range Delay Counter is operating in the self-test mode. The total code acquired light will be converted into a switch-light. The switch will (enabled during self-test) select either a 25% or 100% correlation level.

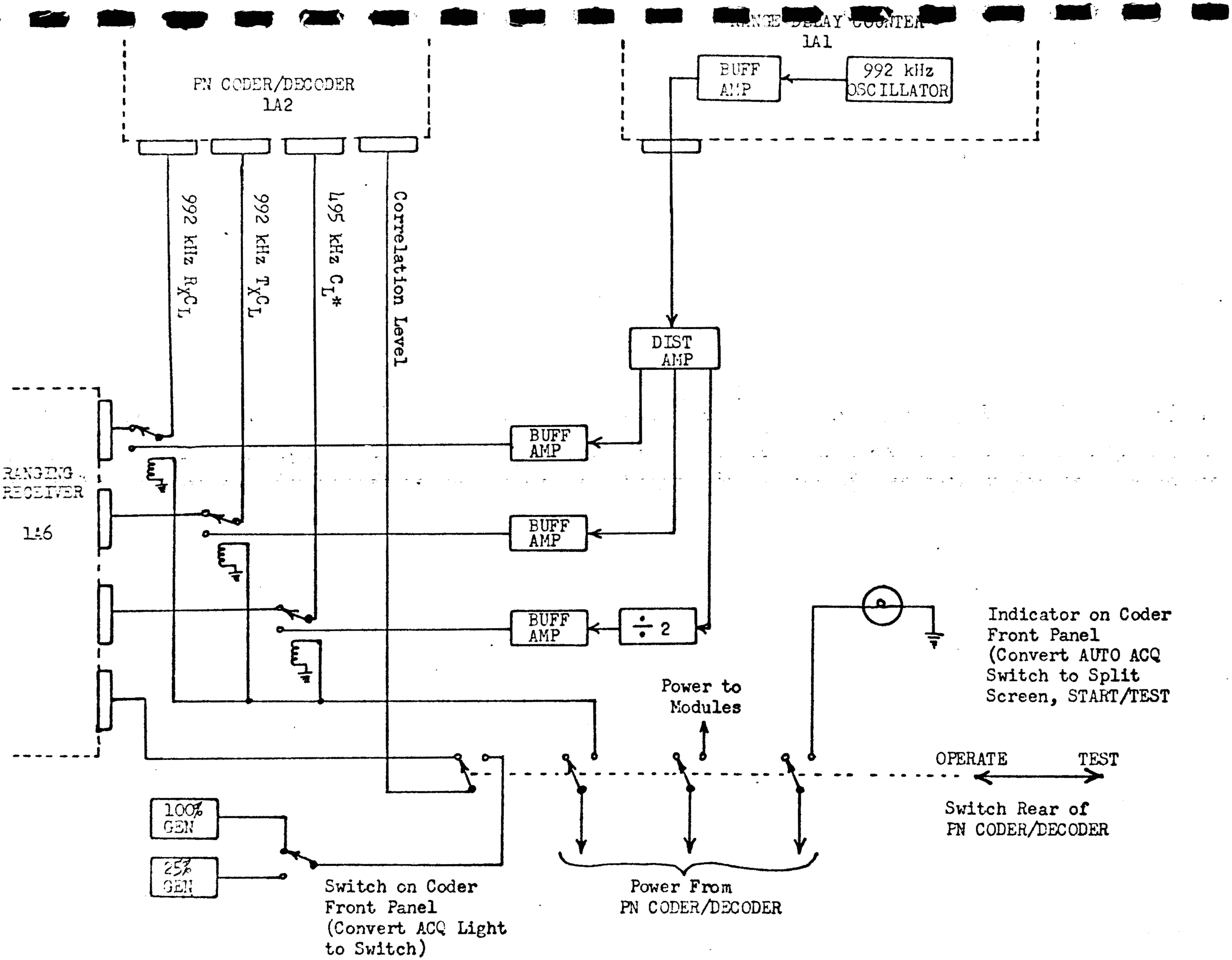


Figure 5-3. Ranging Self-Check Block Diagram

The operator may set the Coder and Range Delay Counter in the self-test mode by:

1. Set the MANUAL-TEST switch to TEST.
2. The digital system is now ready for self-test operation and it is suggested that the operator follow the Coder/Range Delay Counter self-test procedure outlined in the operational manual.

5.4 PCM BIT ERROR DETECTOR

The performance of the 1.024 MHz Bi-Phase PCM Modulator in the transponder can best be determined quantitatively by measuring the bit-error rate under various conditions. For more complete tests, then, it is recommended that a message generator, bit synchronizer, and bit-error detector be used. The CCS Test Set can be easily modified to allow the addition of this equipment. An example of how it could be set up is shown in Figure 5-4.

5.5 DYNAMIC RANGING SUBSYSTEM AND DYNAMIC RANGE AND DOPPLER SIMULATOR

The present Ranging Subsystem was designed to test transponders. As such, it was not designed to be used with a changing (dynamic) range or doppler. For experimental purposes, it might be desirable to have this capability.

Modifications to the present CCS Test Set that would allow this, are as follows:

1. Substitution of a VCO loop for the automatic phase control loop in the Ranging Receiver.
2. The addition of a code clock transfer loop to the Ranging Receiver.
3. The addition of a dynamic r-f doppler unit.
4. The addition of a dynamic ranging unit. This unit should also allow the presetting of any "Start" range.

The first two items are relatively straight foreward, and could be accomplished by the addition/change of several modules in the ranging drawer. A switch could

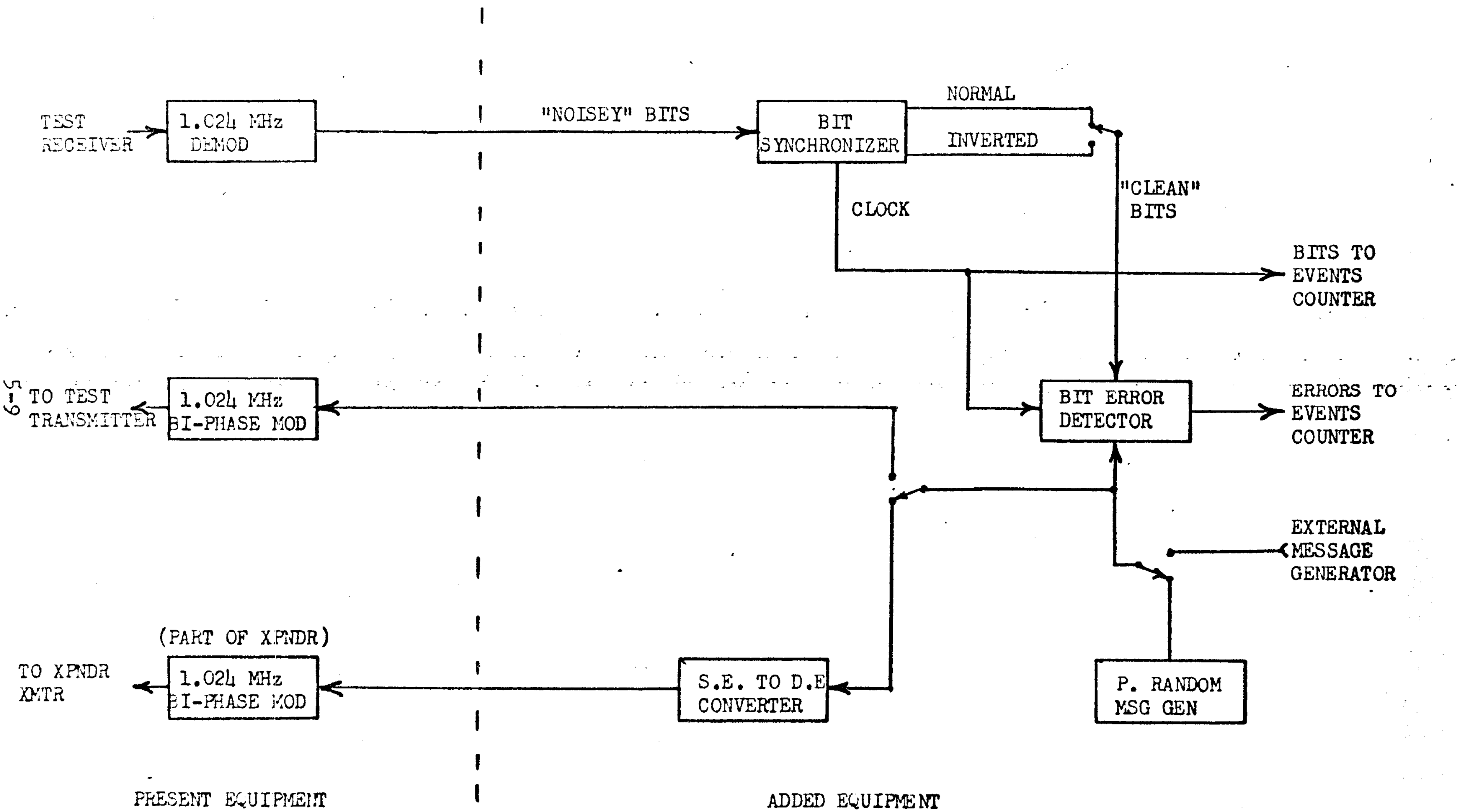


Figure 5-4. PCM Bit Error Detector

select the present (static) method or the dynamic method. There are several ways that the last two items could be accomplished. One way is shown in the block diagram, Figure 5-5.

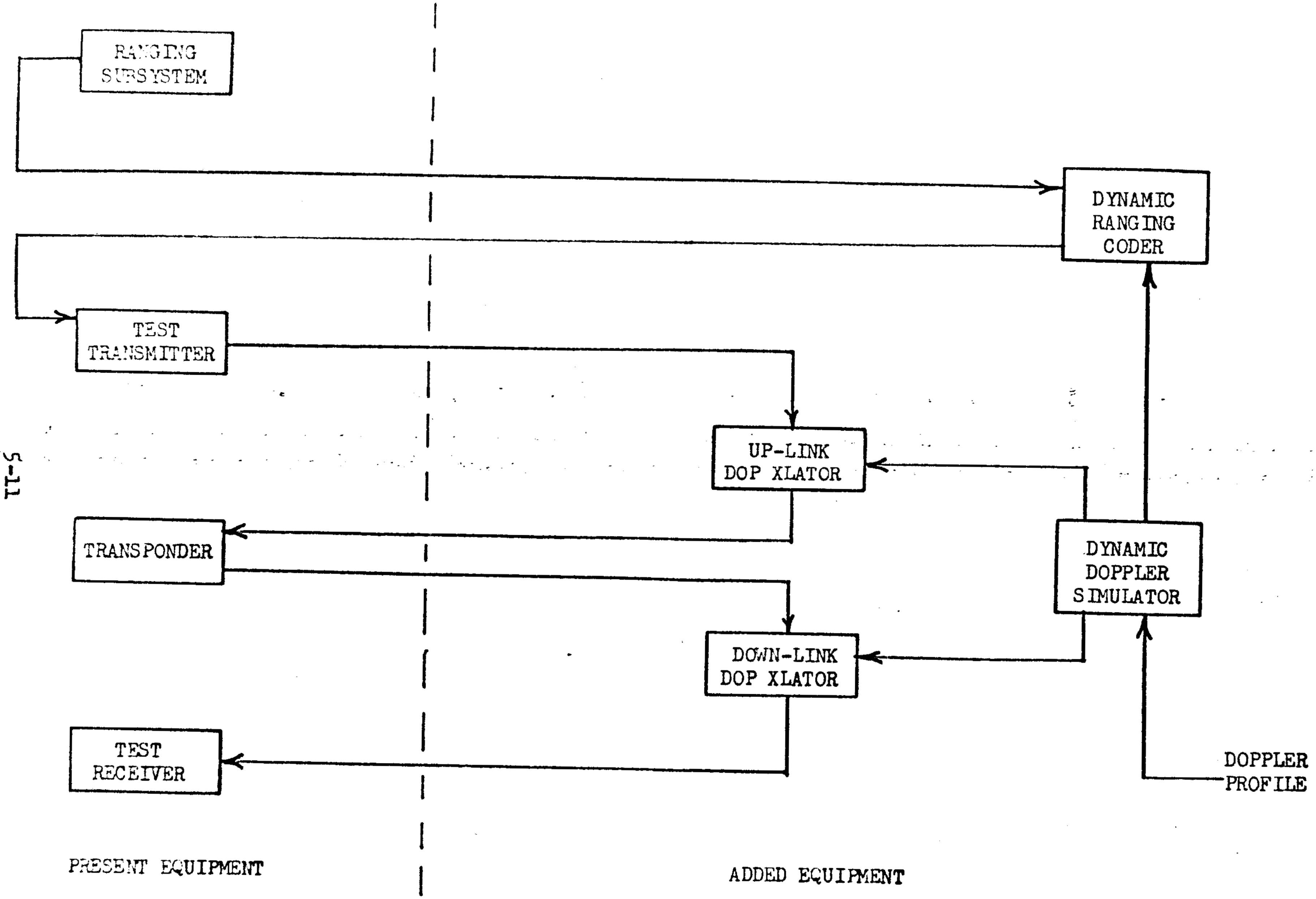


Figure 5-5. Dynamic Range and Doppler Simulator

PD # 372

PROJECTED/ACTUAL EXPENDITURE RATE
TOTAL COST LEVEL

CONTRACT # NAS 8-20546